

**The Joint Modular Intermodal Container,
is this the future of Naval Logistics?**

by

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**Submitted to the Department of Ocean Engineering
in Partial Fulfillment of the Requirements for the Degrees of**

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and
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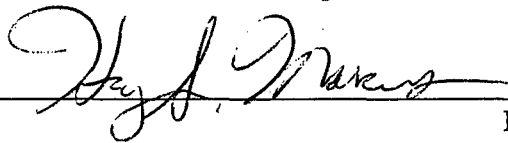
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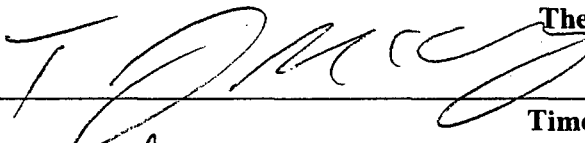
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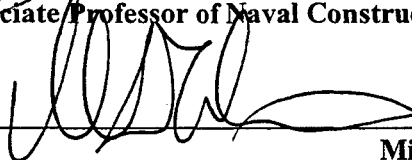
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ABSTRACT

Under the fiscal reality of the 21st century military budget, the typically manpower intensive United States Navy has had to learn to do more with less of everything, in many cases specifically less sailors. One mission area that is prime for manpower reduction is naval logistics. JMIC, the Joint Military Intermodal Container is a combined Naval Sea Systems Command/ Office of the Chief of Naval Operations (NAVSEA/OPNAV) program that is designed to change the way the United States Navy conducts logistics. Automation and efficiency improvements inherent to the JMIC program are proposed to drastically lower the manpower requirements and complexity of the US Navy logistics pipeline. JMIC is a program in the very early stages of development. This thesis will examine some of the operational and technical challenges associated with incorporating JMIC into the United States Navy, and ultimately United States Military logistics architecture.

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LIST OF ABBREVIATIONS, ACRONYMS, AND SYMBOLS

AFS	Combat Stores Ship
AGS	Advanced Gun System
AIT	Automated Information Technology
AOR	Area of Operations
CG	Guided Missile Cruiser
CLF	Combat Logistics Force
CNO	Chief of Naval Operations
CONREP	Connected Replenishment
CONUS	Continental United States
CV	Aircraft Carrier (Conventional)
CVN	Aircraft Carrier (Nuclear)
CVX	Next Generation Aircraft Carrier (aka CVN-21)
DDG	Guided Missile Destroyer
DD(X)	United States Navy New Destroyer Concept Design
DoD	Department of Defense
DUSD (L&MR)	Deputy Undersecretary of Defense for Logistics and Material Readiness
FAS	Fueling at Sea
FFG	Fast Frigate
HiCASS	High Capacity Alongside Sustainment
ISO	International Standards Organization
JMIC	Joint Modular Intermodal Container
LCS	Littoral Combat Ship
LHA	Amphibious Assault Ship
LHD	Amphibious Assault Ship
LPD	Amphibious Transport Dock Ship
MCM	Costal Minehunter Ship
MHC	Mine Countermeasures Ship
MPF(F)	Maritime Propositioning Force (Future)
NAVSTORS	The Naval Stowage and Retrieval System

LIST OF ABBREVIATIONS, ACRONYMS, AND SYMBOLS (Cont.)

NSWC	Naval Surface Warfare Center
NSWCCD-SSES	Naval Surface Warfare Center, Carderock Division, Ship Service Engineering Station
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
OHE	Ordnance Handling Equipment
OPNAV	Office of the Chief of Naval Operations
PHS&T	Naval Packaging, Handling, Storage and Transportation Center
PEO-Carriers	Program Executive Office- Carriers
RAS	Replenishment at Sea
RCS	Radar Cross Section
RF Tag	Radio Frequency Tag
RFID	Radio Frequency Identification Tagging
SIB	Storeroom-in-a-Box
SPI	Standard Payload Interface
STREAM	Standard Tensioned Replenishment Alongside Method
T-AE	Ammunition Ship
T-AKE	Auxiliary Stores and Ammunition Ship
T-AOE	Fast Combat Support Ship
T-AOE(X)	Next Generation AOE
TAV	Total Asset Visibility
TOC	Total Ownership Cost
UNREP	Underway Replenishment
USTRANSCOM	United States Transportation Command
VERTREP	Vertical Replenishment

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EXECUTIVE SUMMARY

The fiscal reality of the 21st century defense budget has forced the United States Military to look at ways to accomplish more missions for less money. One area that is prime for efficiency improvements is military logistics.

Currently there are many proposals to introduce small standard sized container systems into the military logistics architecture, replacing the almost universally used wooden pallet. Small intermodal container systems are poised to drastically change the way the United States Military logistics pipeline operates. Much like the 1960's commercial shipping conversion from break-bulk supplies to standardized containers, military logistics conversion from shrink-wrapped wooden pallets to standard sized intermodal containers offers a wide variety of cost savings and efficiency improvements.

The purpose of this thesis was to study the proposed introduction of one type of container system, JMIC – the Joint Modular Intermodal Container, into the United States Navy logistics architecture. JMIC is a small intermodal container system currently under development by the Naval Surface Warfare Center, Indian Head Division, Package-Handling-Storage-and-Transportation center at Naval Weapons Station Earle, New Jersey. OPNAV N42 is sponsoring the development program.

The thesis starts by investigating some of the technologies needed to make small intermodal container systems work most efficiently within the naval logistics architecture, including Heavy UNREP, Radio Frequency Identification Tags, container blast hardening, and shipboard automated warehousing.

After investigating required technologies, a proposed concept of operations (CONOPS) is then developed for the JMIC system. The CONOPS reviews processes such as pier-side loading of JMIC containers, use of JMIC in underway replenishment, and use of JMIC in the Navy concept known as Seabasing. As part of developing a CONOPS, a determination of JMIC compatibility with the current and future Naval fleet is conducted.

Finally the study concludes by looking at some of the commercial alternatives to the JMIC, and JMIC's development road ahead. The conclusion section of the report investigates some of the proposed cost savings associated with the JMIC system, and some of the proposed changes in naval combatant design philosophy that are going to be necessary in order to make the system work.

The overall conclusion of the thesis is that small intermodal container systems such as JMIC do offer a wide variety of potential efficiency improvements and cost savings. However, the problems associated with the widespread implementation of such a system, including legacy and future ship incompatibility are large. The funding path for development and implementation of JMIC into the naval logistics architecture is unclear. What is clear is the development of a truly joint service intermodal container system is going to be difficult and will require a level of collaboration between the services that has not been seen in the past.

The bottom line is JMIC and other systems like it do offer some distinct advantages and capabilities not found in the military logistics architecture today. There are many development, compatibility, procedural, and cost issues that need to be addressed before the system can truly move forward. The purpose of this thesis is to give the reader an idea about some of the issues facing the JMIC system, and perhaps spur areas of further research.

INTRODUCTION

United States Navy sailors cost too much. Under the fiscal reality of the 21st century the United States Navy has had to learn to do more with less of everything, in many cases specifically less sailors. One of the areas that has seen a large manpower reduction, but yet is still primed for further drastic cuts, is Naval logistics. Over the last decade the way the United States Navy resupplies its ships has changed dramatically, with even greater changes still in the planning stages.

From the end of World War II until the end of the Cold War US Naval logistics operated in much the same manner. A naval battlegroup would sit pierside in its homeport waiting to deploy to a foreign sea. Two weeks prior to the battlegroup's deployment date a long line of tractor trailers would begin to form at the head of the pier. One by one the trucks would pull onto the pier up to the foot of the ships brow, where they would unload their pallets of goods. Then the ships crew would then quickly begin to break down the pallets into individual packages, passing the packages up onto the ship using large working parties organized much like 1880's fire brigades. Once all the ships were full with the supplies needed for an extended deployment they would sail off, generally accompanied by one big resupply ship. Periodically at sea the resupply ship would service the ships in the battlegroup with food, fuel, and ammunition as these items were depleted. Once the battlegroup and the resupply ship began to run low on food, bombs, or fuel they would all pull into a friendly foreign port and the working party process would be repeated.

The battlegroup/working party resupply system worked fairly well, if not terribly efficiently, for 40 years because of one thing, sailors. It used to be routine that a battleship would have a crew of 1200 men, a small destroyer a crew of 400-500, and a supply ship a crew of 800. Therefore gathering a working party of 100 men to resupply the ship was not overly detrimental to the daily workload that needed to be performed by the rest of the crew. Also at sea there were plenty of bodies to man the stations taking supplies from the resupply ship, and also plenty of bodies to quickly break those supplies down and stow them below. However, new manning initiatives being pushed by the Navy to save costs will quickly cause this old system to break down. New, less manpower intensive methods, methods more in line with commercial logistics practices should quickly move in to fill the void.

After the demise of the cold war the United States Navy's mission has typically been centered around small regional conflicts and enforcing United Nations embargo policies. Under these new missions the old operational concept of large battlegroups on extended deployments has largely gone away. Ships may still deploy as a battlegroup to a certain area of operations (AOR), typically the middle east, but once they arrive in the AOR the battlegroup will break up into many pieces spread over a large geographical area, each piece performing its own mission and having different logistical needs. An example of this would be a typical Persian Gulf deployment prior to the most recent Iraqi War. While an aircraft carrier may have been steaming around the middle of the Persian Gulf with an escort, typically some of the ships in the battlegroup may have been hundreds of nautical miles away in the Northern Gulf enforcing the United Nations oil embargoes on Iraq, while others may have been thousands of miles away in Indonesian Straits protecting key worldwide shipping lanes. Obviously the old model of one resupply ship keeping up with the needs of the battlegroup was no longer an option. Adding to the difficulty, the unpopularity of the United States political policy, and the rise of regional terrorism had begun to make friendly foreign ports in this area few and far between. Clearly the old logistics supply system was not designed to handle the situations being faced by the US Navy in the post-Cold War era.

Along with operational changes technology has begun to drastically change the way Navy ships are manned and operated. Automation, enabled by advancing computer technology, has drastically reducing the number of men required to normally operate a ship at sea. At the same time the increasingly advanced technology has made the ships much more expensive to build and maintain. This technological innovation was all occurring in the post Cold War military draw down. Therefore, while Navy ships were getting more and more expensive to buy the Navy itself was getting less and less money to purchase them. Obviously something had to change; to this date that change has been a concerted effort to reduce operational costs. Personnel are by far the largest operational life cycle cost of a Navy warship. Thus the Navy has chosen manning reductions as its way to reduce the operational costs of its inventory. These manning reductions are generally enabled by automation through technology. In fact some of the ships being designed today, which are twice the size of a 1980's era destroyer with a crew of 400 men, are being designed to operate with a crew of less than 100.

Unfortunately one area that has not easily lent itself to automation, at least in the United States Navy, is logistics management. Even today in 2005 most Navy ships are resupplied pierside using palletized goods broken down by working parties. At sea the largest container of goods that can be passed between ships is generally pallet size. Contrast this with the commercial shipping industry, which for the last 40 years has been moving non-bulk goods in hyper-efficient container vessels. Containerization lends itself to automation and efficiency in its drastic reduction in material handling requirements. Unloading five tractor-trailers by working party may take 100 men all afternoon, while the same evolution can be accomplished using containers and cranes in under an hour, with only a handful of operators. To this end the Navy is now seriously looking at incorporating containerized material handling capability into its new ship designs. An example of this is the JMIC (Joint Military Intermodal Container) system. JMIC is a proposed program designed to get all branches of the military using the same standard container for transport of most of their non-bulk goods. JMIC looks and operates much like a standard shipping container except that it is, smaller, reconfigurable, and offers some benefits in ease of retrograde (returning empty containers to the original supplier).

Naval logistics has changed drastically since the end of the Cold War. A shifting primary mission and technology have both served to make the old methods of logistics resupply obsolete. New, more efficient delivery methods and new manning techniques have sprung up to replace the old. However, the changes over the last fifteen years will probably pale in comparison to those to occur over the next fifteen as the Navy continues to improve logistics efficiency by moving toward containerization and other highly successful commercial techniques.

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I. CURRENT STATE OF UNITED STATES NAVAL LOGISTICS

The United States Navy has a multi-faceted logistics pipeline. The logistics tools used are generally dictated by the end user requirements. As an example the logistics pipeline and components used to resupply US Navy ships at sea are vastly different from those used to resupply amphibious forces ashore. However, because of these differences, and because of the use of some outdated legacy systems, the entire Naval logistics pipeline shares one thing in common, it is terribly inefficient in terms of manpower required and throughput enabled compared to various commercial logistics practices in use today. To understand these inefficiencies, and to discuss ways of improving them, we must first examine the ways in which the US Navy is currently conducting logistics.

A. SHORE BASED LOGISTICS

The current Navy practice for resupplying ships in CONUS ports is much the same procedure as performed in resupplying a typical suburban grocery store. When a ship is moored in port preparing for an extended underway, trucks will be arriving daily with all manner of palletized goods for delivery. The trucks and pallets will be arriving from wholesalers, for large orders of goods, or intermediate Navy warehouses if the order is not of sufficient size to warrant an entire truck.

Depending on the type of ship, from this point on one of two things will generally happen. Most Naval Logistics Ships, or more formally Combat Logistics Force (CLF) ships, have logistics handling gear and cargo holds sized to handle goods in palletized form. These ships use fork trucks and cranes to load and store the palletized goods for later delivery at sea. However, just because the goods are never broken down from palletized form does not make this a quick and painless evolution. A typical loadout for a deploying CLF ship may be well in excess of 1000 pallets and may occur over a period of many days. Also, because the palletized goods are not standard sized, and contain no ability to be interlocked, often a large amount of blocking and bracing for sea, also known as dunnaging, must be done before the ship can get underway. Some CLF ships have holds designed with pre-placed stanchions to brace cargo for sea, but in others dunnaging typically means having carpenters measure and cut lumber to brace cargo within the ship's hold. For a large loadout, the loading and dunnaging period can stretch as long as 10 working days, drastically affecting the ship's operational availability.

Most US Naval Combatants do not have the logistics handling gear, or cargo holds designed to handle goods in palletized form. For these ships supplies arriving on the pier are normally either loaded aboard to a large open area (i.e. flight deck), via crane, or broken down manually on the pier and passed aboard using conveyors. The common theme here is that large working parties of sailors are needed to break down the palletized goods (on the flight deck or pier), pass them onto the ship (via conveyor or old-fashioned bucket brigade), and then stow the supplies into cargo holds. Depending on the size of the ship and crew, these working parties can consume a large portion of the ship's workforce.

Palletized delivery of supplies creates an accounting headache common to both CLF and combatant ships, but it is especially painful for the combatants, where the pallets are broken down prior to stowage. In some instances the pallets may be bar-coded, enabling electronic accounting, but many times most on-pier inventory accounting is done via old fashioned paper and pen, for later entry into a computerized databank.

In 2005, US Naval ships are loaded pierside in much the same method, using many of the same technologies, as break-bulk commercial ships were loaded, circa 1960.

B. CONNECTED REPLENISHMENT

Connected Replenishment, or CONREP for short, is a method US Navy ships use to transfer supplies at sea. In general terms it is a method where two ships steaming alongside each other are connected via a high-tension wire, in Navy parlance it is known as STREAM, or Standard Tensioned Replenishment Alongside Method. The high-tension wire is used as a supporting structure for a series of cables, winches, pulleys, and hoses that are used to pass supplies back and forth between the two ships. Food, ammunition, replacement parts, and occasionally personnel are all passed between ships using this method. Figure 1 depicts a common CONREP setup between two ships¹. Fuel is also passed between ships using the CONREP architecture in a process called FAS, or Fueling At Sea. The fuel transfer setup is depicted in Figure 2².

¹ "Underway Replenishment," [Retrieved from www.fas.org/man/dod-101/sys/ship/unrep.htm]. 11 NOV 04.

² Ibid.

Figure 1: Typical CONREP Setup

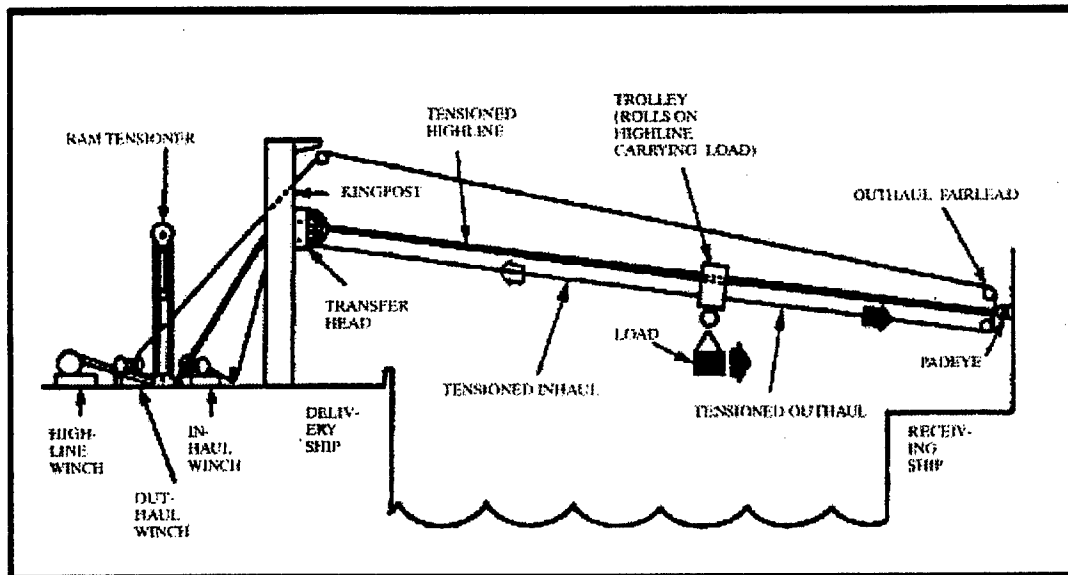
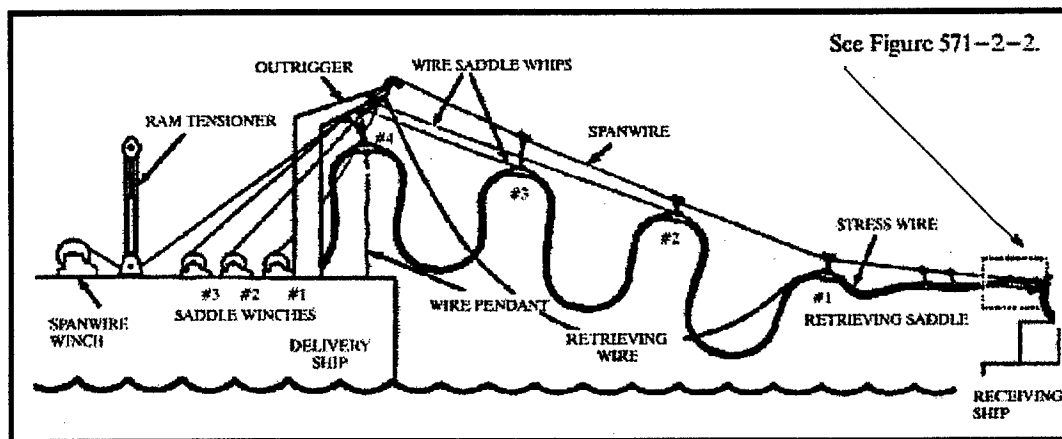


Figure 2: Setup for Fueling At Sea (FAS)



Replenishment at sea (RAS) has gone through many iterations of technological improvement in the modern Navy, and STREAM represents the most recent innovation, although in itself it has been in use for many years. STREAM does offer many benefits over past RAS methods. Improvements such as greater separation between ships (less chance of collision due to bad weather or poor shiphandling), relatively fast cargo transfer rates (compared to older methods), and the ability for a Combat Logistics Force ship to service more than one ship at a time (by servicing a ship to both port and starboard), make STREAM a much more efficient method than past procedures for moving cargo between ships.

1. Current Limits

The main disadvantage of the STREAM rig CONREP system is its limited cargo weight capacity, especially in heavy sea states. The current weight limit for STREAM rig cargo transfer is 10,000 lbs in Sea State 3, and only 5,700 lbs in Sea State 5³. Palletized food transfer is generally not hindered by these limits, but certain types of ammunition and replacement parts, i.e. aircraft engines being passed to an aircraft carrier, can be. More than being a limit of what types of supplies can be passed; the weight limits serve as a limit to how these supplies can be most efficiently packaged. For example it may be most efficient to transfer certain types of supplies in tandem rigs, small shipping containers, or on specially designed skids, but the current weight limits serve to make these methods untenable. The 5,700 lb limit can be increased in good weather by bringing the ships closer together, but this brings ship safety issues into play and forces weather restrictions on UNREP operations.

2. Heavy UNREP

There has been significant development effort over the last few years to increase the weight limits associated with STREAM rig CONREP. Naval Sea Systems Command (NAVSEA) Port Hueneme Underway Replenishment Department has been testing a concept that it projects will allow up to 12,000 lbs of cargo to be transferred at sea in up to Sea State 5⁴. This increased weight limit project is being termed "Heavy UNREP".

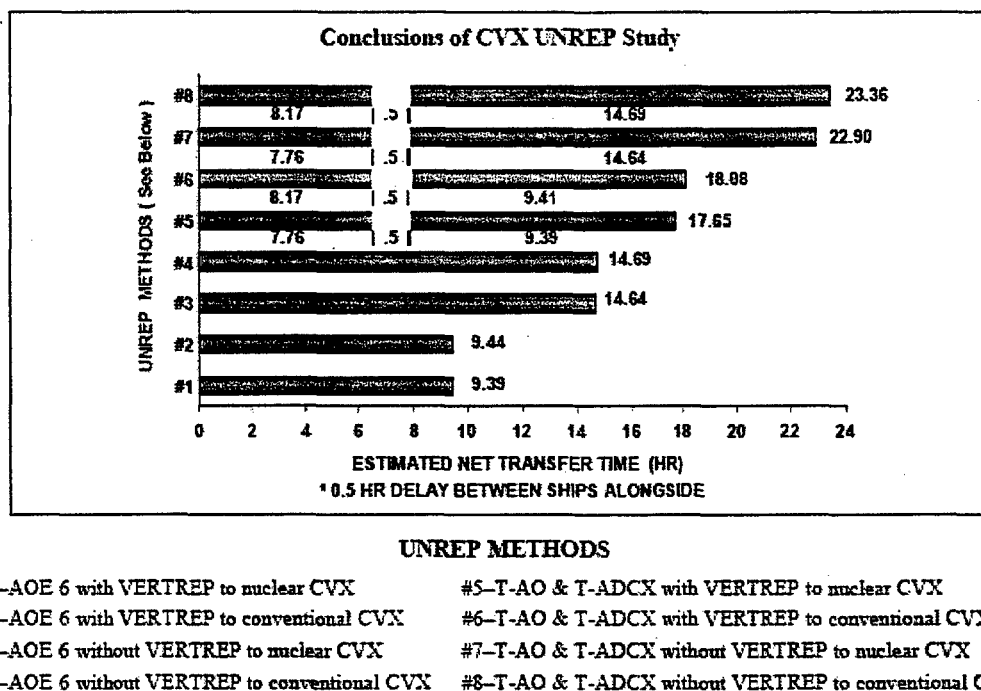
³ "Port Hueneme Heavy Underway Replenishment Project," [Retrieved from www.nwcportal.nwc.navy.mil/nwdc/sea_basing/Sea%20Basing%20Background/Heavy%20Unrep%20%26%20PHD%20Demo%20Summary%20Sheet.pdf]. 19 NOV 04.

⁴ Ibid

The main driver behind Heavy UNREP has been the recognition that in wartime scenarios, the Navy's capital ships, its aircraft carriers, are being taken off-line too long to load ordnance in a high-sortie environment. Figure 3 shows estimates of required UNREP times for CVX under a variety of different scenarios after five days of high sortie operations⁵.

Considering the increased sortie rates of the next generation aircraft carriers, UNREP developers soon determined that the current STREAM system, with its 5700 lb limit was not going to meet increased material transfer requirements in a reasonable length of time. What also has to be considered when looking at Figure 3 is that it is only showing alongside time. It does not take into account the

Figure 3: CVX UNREP Duration

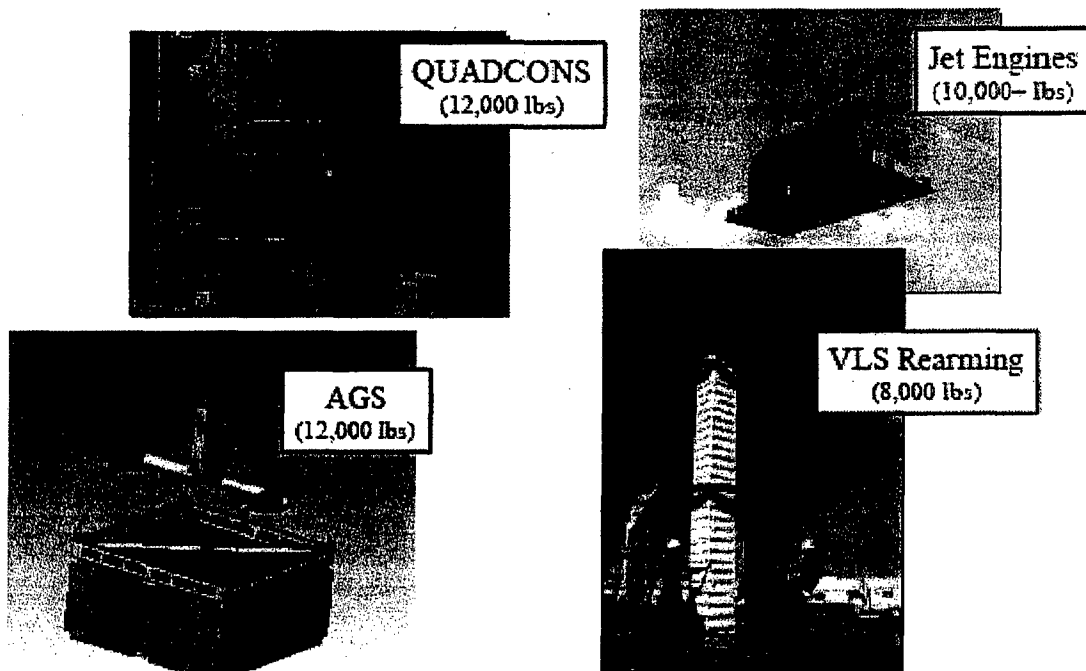


time the aircraft carrier would be off-line to transit to the UNREP area, or the time needed for the aircraft carrier to clear its decks of all cargo to resume flight operations. When these two factors are taken into account it becomes readily apparent why the current STREAM system is not sized to handle CVX.

⁵ "Preliminary Study of CVX UNREP After Five Days of High-Sortie Action," Underway Replenishment Department, Port Hueneme Division, NSWC. 22 JUN 98.

Heavy UNREP capability has three main benefits over current STREAM technology, one of course is that it allows for a heavier load to be passed between ships and therefore expands the subset of supplies that can be passed via STREAM rig, Figure 4. The second major benefit is by increasing the STREAM weight limit the Heavy UNREP system allows supplies to be more efficiently packaged, therefore enabling a greater throughput for the entire CONREP evolution. In fact the threshold throughput value for the Heavy UNREP system is 150 tons/hour/rig, or four times that of the current STREAM system⁶. The third benefit is that Heavy UNREP systems are much more automated than current STREAM technology. It is estimated that it will take approximately 40% less personnel to operate a Heavy UNREP station than a current STREAM station⁷.

Figure 4: Heavy UNREP Enables New Loads to be passed Between Ships

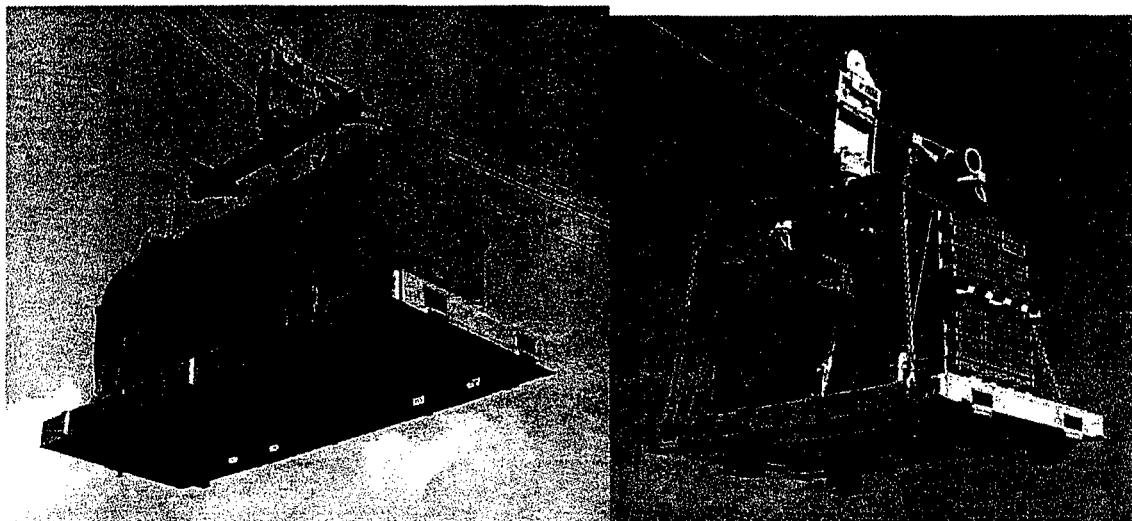


⁶ "Port Hueneme Heavy Underway Replenishment Project," [Retrieved from www.nwcportal.nwc.navy.mil/nwdc/sea_basing/Sea%20Basing%20Background/Heavy%20Unrep%20%26%20PHD%20Demo%20Summary%20Sheet.pdf]. 19 NOV 04.

⁷ "Heavy UNREP System Design Features," Underway Replenishment Department, Port Hueneme Division, NSWC. 15 FEB 05.

By allowing for a larger transfer weight the Heavy UNREP system will allow for some cargo to be transferred on UNREP Skids (See [Figure 5](#)), enabling a greater throughput and perhaps more importantly enabling faster stowage of material on the receiving ship⁸. Ships will need large elevators to take full advantage of the benefits provided by Heavy UNREP Stream rigs, therefore the capability is only initially being proposed for aircraft carriers, large deck amphibious ships, and Combat Logistics Force vessels.

Figure 5: Heavy UNREP Skids

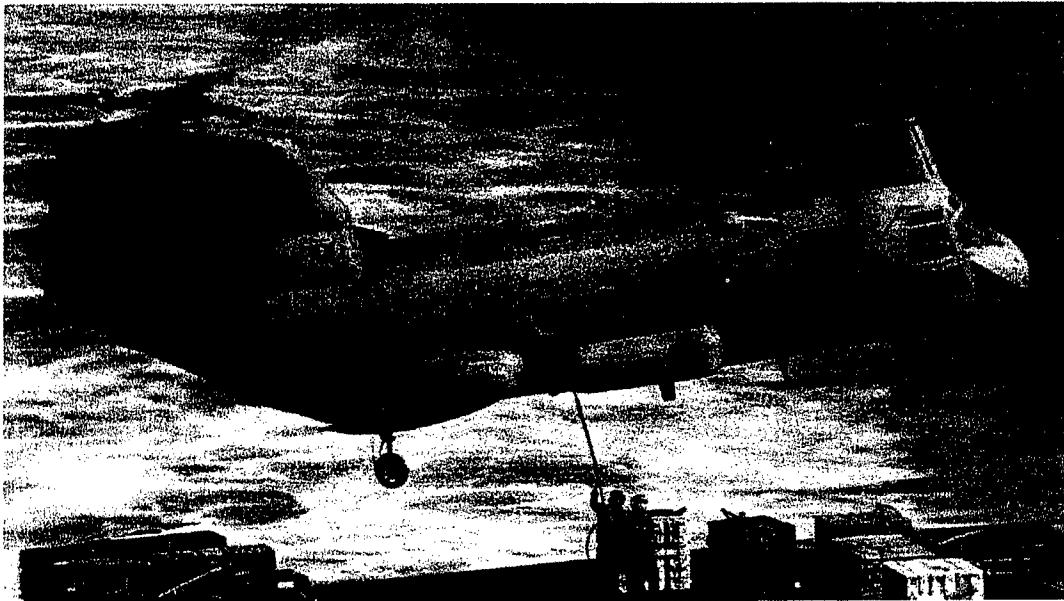


⁸ "FNC Heavy Unrep Skids," [Retrieved from www.nwcportal.nwc.navy.mil/nwdc/sea_basing/sea%20basing%20Background/FNC%20Heavy%20Unrep%20Skids.pdf]. 20 NOV 04.

C. VERTICAL REPLENISHMENT

Almost every class of US Naval Ship has a helicopter capable flight deck. Vertical Replenishment or VERTREP is a method by which two seagoing ships transfer supplies using helicopters as the transfer platform (see Figure 6)⁹.

Figure 6: Helicopter Performing VERTREP Operations



VERTREP can be a very quick and efficient means of transferring cargo between ships but it does have its limitations. Cargo transfer rates compare favorably with CONREP and are normally determined by a variety of variables; such as ship separation distance, ship's flight deck size, and experience of the crew loading the supplies on the flight deck. VERTREP does offer the benefit that ships do not need to be steaming directly alongside one another to transfer cargo, thereby reducing the chance of a collision in a mishap, but the further the ships are apart, the slower the cargo transfer rate. Perhaps the biggest drawback to VERTREP is the weight limit of the cargo that can be transferred. Cargo weights are of course based on helicopter carrying capacity and the US Navy's current, soon to be replaced, heavy-lift helicopter is the CH-46 Sea Knight.

⁹ "CH-46E Sea Knight," [Retrieved from www.fas.org/man/dod-101/sys/ac/ch-46.htm]. 21 NOV 04.

The Sea Knight has an external cargo capacity of approximately 4000 lbs, depending on configuration, which is less than even the current STREAM method¹⁰. Working under these limitations VERTREP will continue to be an efficient method to transfer lightweight supplies, but is unlikely to be able to meet future needs of transferring efficiently packaged cargo.

D. AMPHIBIOUS LOGISTICS

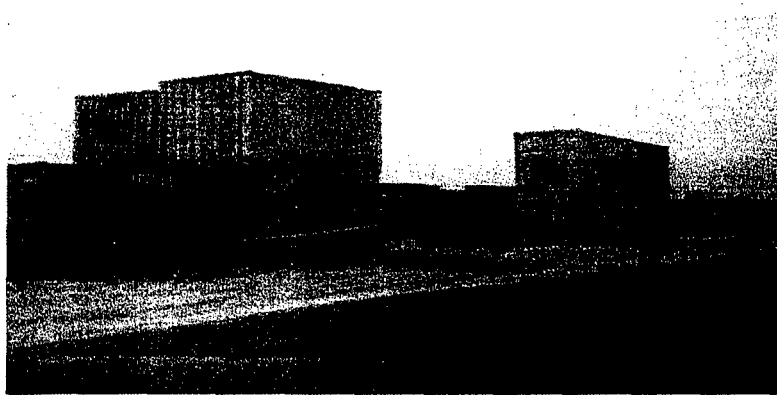
The term "Amphibious Logistics" is a bit vague in its definition. What it is trying to describe is the process of logistically supporting an amphibious operation. Of course amphibious operation is also a very general term and the means of supporting one logistically can be vastly different depending on the scope of the operation. For example, the logistical demands of Marines landing on a contested beachhead are very different from those of transferring a Marine division ashore for inland operations. Support of a contested beach landing is the mission the current United States Navy Amphibious Fleet was designed for, and in this regard they are world class.

A changing world order has made the support of a Marine division ashore the more difficult part of the amphibious logistics puzzle. Traditionally once Marines had been put ashore and secured the landing area they would be re-supplied by "Black Hulls", which in general refers to different variants of commercial and government-contracted shipping. The problem with the Black Hull re-supply method is that it tends to create what is called an "Iron Mountain" in the receiving port, see Figure 7¹¹. The "Iron Mountain" being a less-than-affectionate term for the large amount of material that is disgorged onto the beach from the holds of these super-sized ships. The large amount of material presents many problems, sorting it is a logistical nightmare, protecting it is an operational headache, and even placing it ashore is becoming a political hot potato in this era of strained United States-Middle East relations. Currently there are many development efforts to move the "Iron Mountain" off the beach and eliminate the need for a host nation in order to conduct worldwide military operations.

¹⁰ Ibid

¹¹ Joint Inter Logistics Working Group Presentation. NSWCIHD PHS&T. 08 DEC 04.

Figure 7: "Iron Mountain" Forward Logistics Area



E. INHERENT INEFFICIENCIES

Although the current United States Navy logistics pipeline has served, and continues to serve, the Navy's needs, many aspects of it are inherently inefficient. In order to fully realize the Chief of Naval Operations' (CNO) goals for Sea Power 21 many aspects of the current logistics pipeline will need to be upgraded.

First and foremost the US Navy needs to lower the manpower requirements for its logistics pipeline through the use of advanced technology and automation. Currently almost all facets of Navy logistics are manpower intensive operations. Excessive material handling and accounting requirements due to a lack of technological infusion are handcuffing development efforts to increase the overall logistics pipeline efficiency. Some key areas need to be addressed in order to lower the logistics manpower requirements:

1. Move toward standardized packaging that can be preloaded and pre-staged to enable efficient transfer. A move toward some sort of standard containerization or UNREP skids is necessary, not only to improve transfer speeds, but more importantly decrease the times needed for retrieval and stowage of material, which are already lagging behind material transfer speeds and causing situations such as in Figure 8¹².

Figure 8: Manpower Intensive Strike-down Operations

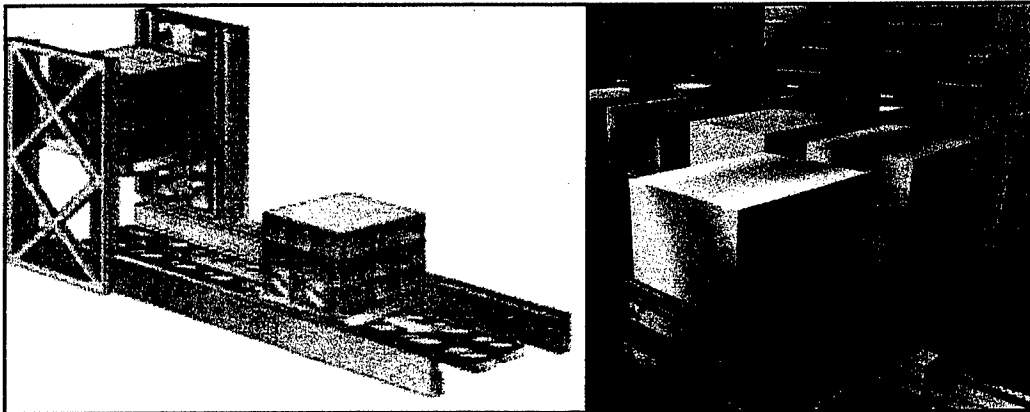


¹² Tedesco, Mathew P. "Shipbuilder's Perspective on Sea Basing Technologies," Presentation to The National Academies Naval Studies Board. 09 SEP 04.

2. Incorporate automated accounting technology. Too many man-hours are being spent on inefficient and relatively inaccurate paper-based accounting methods. The industry standard for automated accounting technology is quickly becoming Radio Frequency Identification Tagging (RFID). This technology needs to be included into any sort of standardized packaging adopted by the US Navy. In fact the Department of Defense has already specified that RFID tags will need to be included with all parts supplied at the pallet level, starting in 2007¹³.

3. New ships need to be designed with “Smart Warehousing” technology. Ships like the one depicted in Figure 8 have no means of sorting and storing supplies automatically. All storage and retrieval of supplies involves a sailor, perhaps with the aid of an elevator or package conveyor, physically manipulating the object. If standard packaging and automated accounting technology are adopted, the next step will be to incorporate “Smart Warehousing” technology, using Figure 9 as an example, into future ship designs¹⁴.

Figure 2: Smart Warehousing Concepts



¹³ “Radio ID Tagging Aims to Improve Military Logistics,” [Retrieved from www.defenselink.mil/news/Sep2004/n09142004_2004091411.html]. 14 SEP 04.

¹⁴ Tedesco, Mathew P. “Shipbuilder’s Perspective on Sea Basing Technologies,” Presentation to The National Academies Naval Studies Board. 09 SEP 04.

II. JMIC: ONE PROPOSED SOLUTION

JMIC, or the Joint Modular Intermodal Container, is a system that directly or indirectly addresses many of the inefficiencies in the current United States Navy logistics pipeline. The JMIC system is an attempt to incorporate a relatively small, standardized, intermodal, interlocking container into the United States Military logistics architecture. Utilizing JMIC can help alleviate the inefficient box-within-a box-within-a-box concept that is all too common in current military logistics practices¹⁵.

This thesis will focus on the JMIC system developed by the Naval Surface Warfare Center's (NSWC) Packaging, Handling, Storage and Transportation Center (PHS&T), and its proposed uses in United States Navy and Marine Corps logistics applications. There are different variants of intermodal container systems currently being studied and developed by various agencies within the Department of Defense (DoD) and where applicable the capabilities and limitations of these differing systems will be compared to the PHS&T JMIC system being studied, but further analysis of the competing systems will be left for later research.

JMIC, as proposed by the PHS&T center, consists of an extruded aluminum container with a tare weight of 330 lbs, a loaded capacity of 3000 lbs, and a 44" X 54" X 42" (height) footprint. The basic JMIC container is shown in Figure 10¹⁶. Some of the features of the container that make it such an improvement over current logistics technology are the container's ability to be interlocked with other JMIC containers into efficient packaging configurations in the commercial 20 ft ISO container, ISO flatrack, or the Air Mobility Command's 463L pallet, Figure 11¹⁷. Also, once emptied, the JMIC container has the ability to be collapsed into greater than a 3-to-1 stack ratio for easier retrograde, Figure 10.

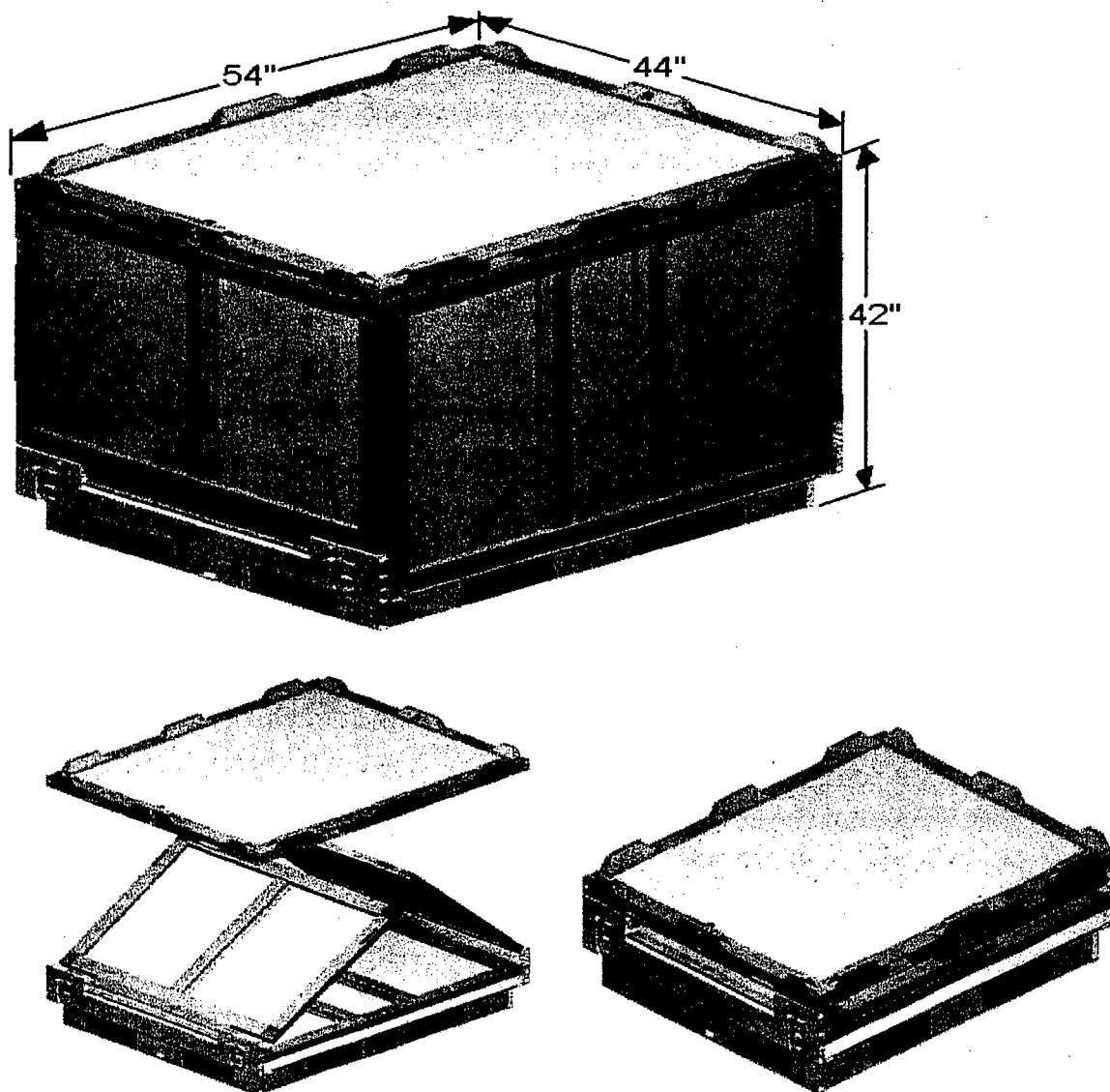
The initial funding for JMIC has been to look at the system as a better method for logistics transfer of ordnance, and many of the features of the current JMIC prototype have been incorporated because of this mission profile. However, JMIC system-wide efficiencies can also be utilized with other military supplies. In general use of the JMIC system within the military logistics architecture will be a tradeoff study of efficiencies gained vs. JMIC container added cost and weight.

¹⁵ "Joint Modular Intermodal Container," Draft Paper by Naval Surface Warfare Center Indian Head Division, Detachment Earle, Naval Packaging, Handling, Storage and Transportation Center. 14 DEC 04.

¹⁶ Ibid.

¹⁷ Ibid.

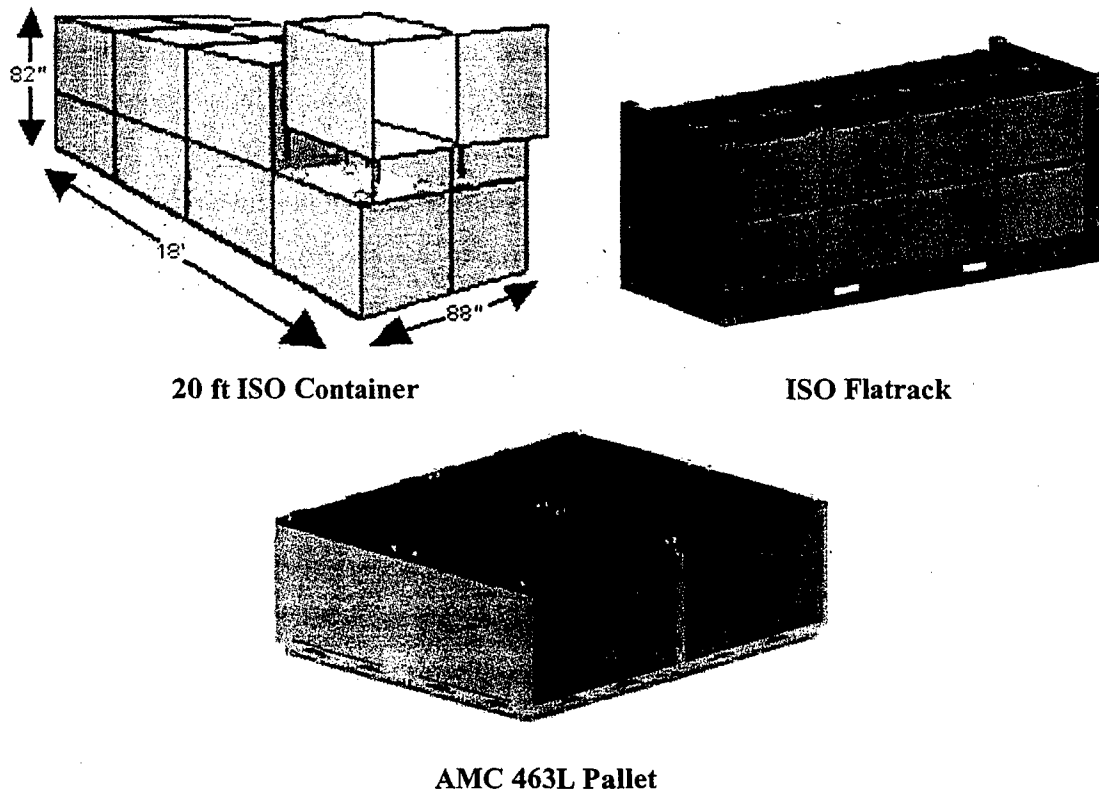
Figure 10: Joint Modular Intermodal Container



In order to make JMIC a system more widely suitable for a variety of military supplies and transport methods a “family” of JMIC type containers is being studied, using differing materials for cost/weight savings and capacity variations¹⁸. Some examples include a lightweight JMIC for air transport, and a low-cost material (plastic) JMIC for low-value commodities.

¹⁸ Ibid.

Figure 11: JMIC Interaction With Common Logistics Pallets and Containers



A. COMPONENTS OF A JMIC SYSTEM

The current full-size JMIC prototype is an extruded aluminum container. There are proposals to develop JMIC's out of such exotic materials as Titanium, and low-tech variants out of commodity materials such as recycled Polyethylene. There are also proposals to develop JMIC's in a variety of differing dimensions, such as half or double the size of the current prototype¹⁹. A working JMIC logistics transport system will need to consist of thousands of containers in order to meet thresholds for economics of scale and availability. As a reference the Air Force alone has over a quarter of a million 463L pallets to serve its Air Mobility Command logistics requirements²⁰.

¹⁹ Ibid

²⁰ Joint Inter Logistics Working Group Presentation: NSWC IHD PHS&T. 08 DEC 2004.

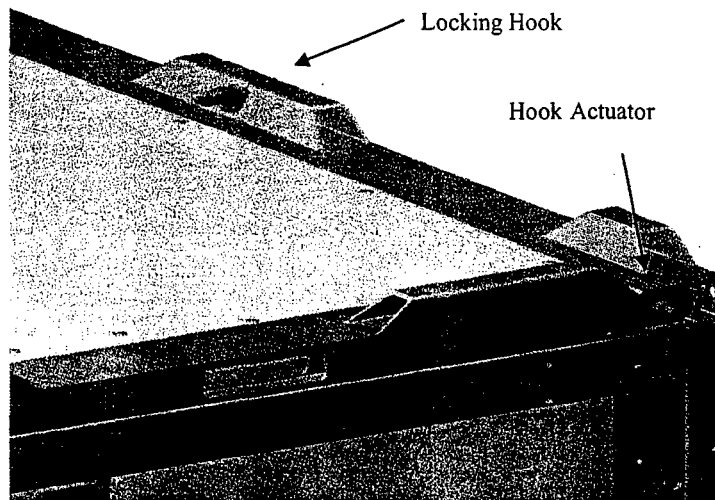
The JMIC system will likely consist of a “family” of containers of various sizes, cost, and weights to serve the differing services needs. In the beginning of the program each variant of the JMIC will probably have differing attachment hardware and lifting points in order to best function within the architecture of each services legacy systems. As the JMIC program becomes more mature it is theorized the new military logistics architecture will be designed to operate under JMIC standards and as legacy systems are decommissioned the “family” of JMIC’s should become more and more standardized, especially in terms of attachment hardware.

Even though it is likely the JMIC system will initially be a somewhat varied grouping of containers there are some features that will be common to each container within the system:

1. **Container Interlocking:** All JMIC’s will need to have the ability to securely interlock with other JMIC containers. Interlocking ability is one of the main efficiency drivers of a JMIC system and one of the main inefficiencies of palletized goods transport. Manpower decreases in military logistics and increased optempo requirements on military logistics assets are going to require fast turnaround times with a minimum of material handling. The military can no longer afford the time or manpower necessary to cut lumber to dunnage a pallet into a ship’s hold, or strap multiple tiedowns onto pallets to secure them within an airframe. By having the JMIC containers securely interlock the amount of dunnaging required for transport is severely reduced or eliminated altogether. Figure 12 depicts the current interlocking mechanism on the JMIC prototype²¹.

²¹ JMIC Concept Presentation. Brief given by Naval Packaging, Handling, Storage and Transportation Division. 07 DEC 04.

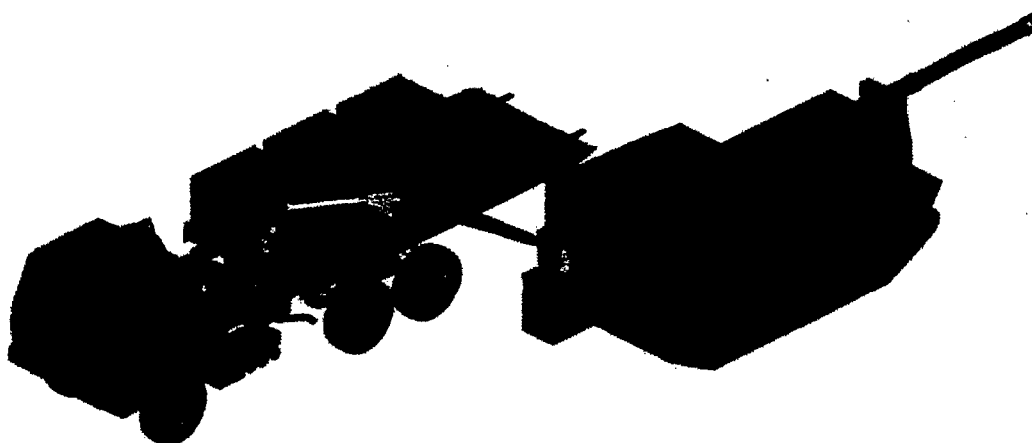
Figure 12: JMIC Container Interlocking System



2. **Automated Accounting Technology:** The Department of Defense has mandated that by 2007 all pallets of military supplies must be outfitted with Radio Frequency Identification Tags (RFID). This mandate will of course apply to the JMIC system as well.
3. **Collapsibility for Easier Retrograde:** Most 21st Century military supply concepts involve efficiency improvements gained by attempting to eliminate the intermediate supply depot and delivering goods to the end user in their original transport packaging, [Figure 13](#)²². However, because the end user is typically a small sized unit, operating specialized combat equipment, they are ill equipped to deal with large, empty shipping containers. Therefore efficiency gains in transport would be offset by container costs if the empty containers had to be abandoned on the battlefield. Collapsibility allows the end user to store the empty shipping containers in a relatively smaller space for retrograde upon further resupply.

²² "Study: Sustainment Package Size, Scalability, Collapsibility, and Expendability," Brief by United States Army Combined Arms Support Command, Material Modernization Division, Combat Service Support Directorate. 07 DEC 2004.

Figure 13: Delivering Supplies to the End User in Original Packaging



4. **Standard Attachment Points:** One of the main cost savings associated with introducing a standard sized container system into the military logistics pipeline is through the introduction of standard attachment points for the containers. In the Navy alone, referencing NAVSEA OP2173 (Approved Handling Gear for Weapons and Explosives)²³, there are seventy-two (72) different approved slings used to serve as the interface between various ordnance storage containers and handling cranes, see Figure 14²⁴. Twenty-Four (24) of the seventy-two (72) slings are used as an interface between different unit-sized loads and handling cranes. NSWCIHD-PHS&T business case analysis for JMIC, determined that of the twenty-four (24) slings, three (3) would likely be needed to handle JMIC with its standard attachment points²⁵. By examining Ordnance Handling Equipment (OHE) requirements in a Packaging, Handling, Storage, and Transport study, PHS&T was able to determine that the ninety-two (92) Combat Logistics Force and Amphibious ships in the current United States Naval Fleet were allowed upwards of 72,000 of the ten most common ordnance handling

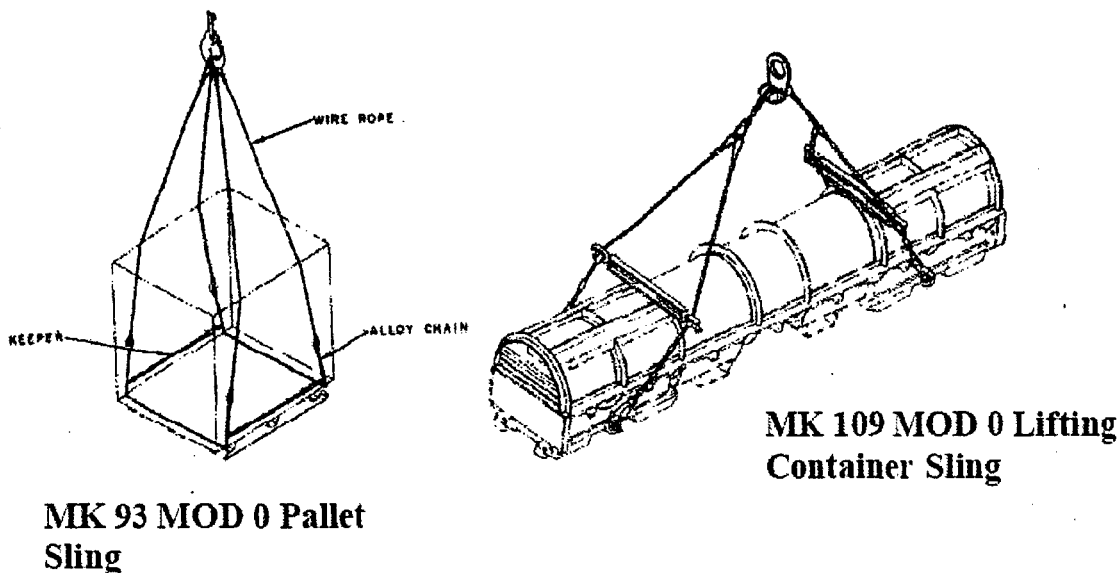
²³ "NAVSEA OP2173, Approved Handling Gear for Weapons and Explosives," [Retrieved from www.navsea.navy.mil]. 20 FEB 05.

²⁴ "Joint Modular Intermodal Container," Business Case Report. NSWCIHD, Detachment Earle, Packaging, Handling, Storage, and Transportation Center. 20 FEB 05.

²⁵ Ibid

slings. PHS&T predicted that by adopting a JMIC like system this number would be lowered to approximately 20,000 slings, others have contested this number because they still predict the need for specialized slings for different individual customers²⁶. The associated savings in sling replacement costs, man-hours for periodic maintenance and weight testing were estimated by PHS&T to be on the order of 2.4 million dollars per year²⁷.

Figure 14: Ordnance Handling Slings



B. JMIC ENABLING TECHNOLOGIES

In order to make JMIC a viable logistics transport system there are many technologies that are currently in development that will need to be included as part of the JMIC logistics package. Because JMIC development is still in its nascent stages, its developers are still unsure of all of the technological advances that will need to be made; however, it is already clear that any JMIC system will require advances in the areas of Radio Frequency Identification Tagging, Container Blast Hardening, Heavy UNREP, and shipboard smart warehousing capabilities.

²⁶ Conversation with Mr. Tom Clevenger, CLF Ammunition Operations Officer, Sealift Logistics Command Atlantic. 07 APR 05.

²⁷ Ibid

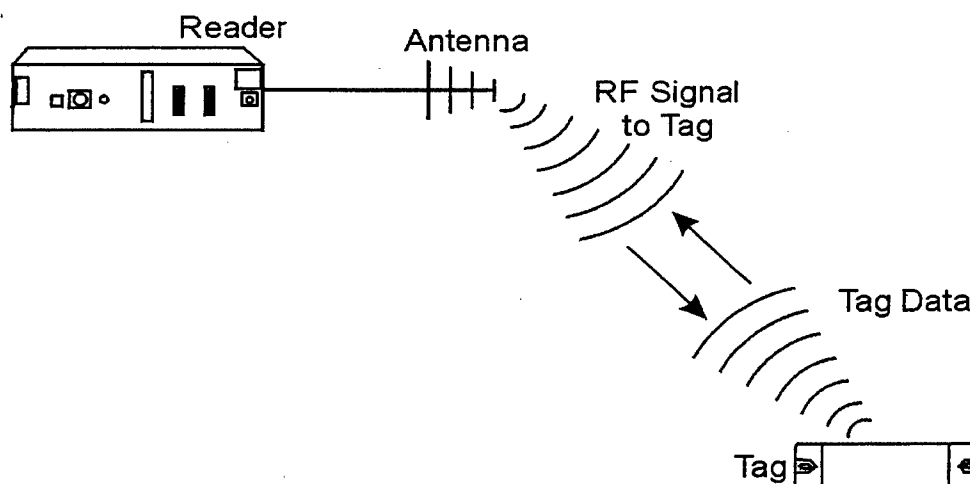
1. Radio Frequency Identification Tagging (RFID)

a. System Components

RFID is an application of technology used to enable AIT, or Automated Information Technology. In general a RFID system consists of three components, an antenna, a transceiver, and a transponder (RF Tag). The RF Tag is electronically programmed with specific information unique to the tag. The transceiver emits signals through the antenna that either query, or power and query, the transponder, depending on the type of RF Tag in use.

The transceiver, antenna, and a decoder are often packaged together in a handheld or fixed mount device. Depending on power output the single piece of equipment is then used to activate and read RF tags from one inch to a few hundred feet away.²⁸ A simple schematic of this arrangement is depicted in Figure 15²⁹.

Figure 15: Schematic of Basic RFID Operations

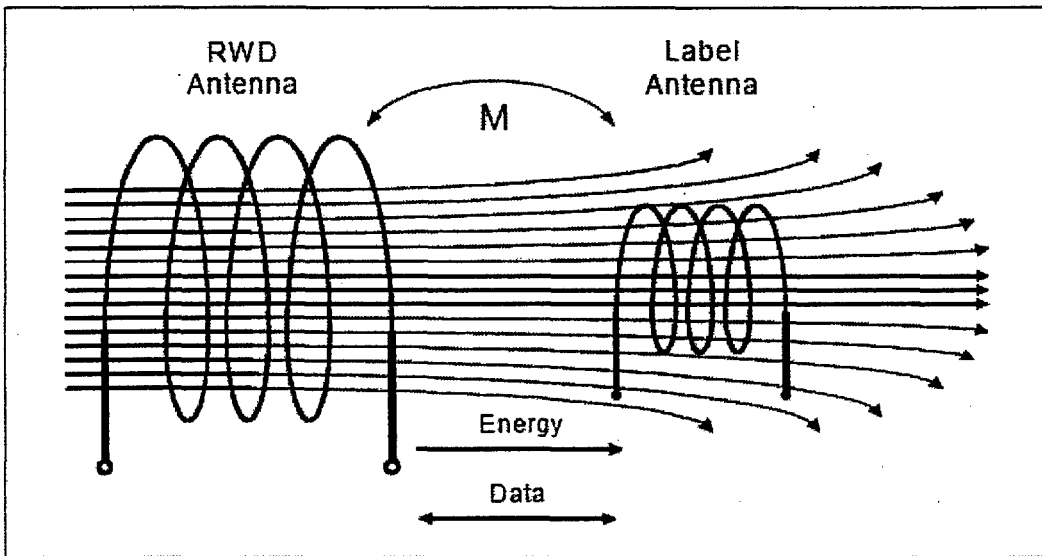


²⁸ Hozven, M., Clark, G., "DoD Supply Chain Implications of Radio Frequency Identification (RFID) Use Within Air Mobility Command (AMC)," MBA Thesis, Naval Postgraduate School, Monterey, California. 01 DEC 03.

²⁹ "Draft Paper on the Characteristics of RFID-Systems," AIM Frequency Forums, AIM FF 2000:001. 01 JUL 00.

There are two distinct types of RF Tags, active and passive, and the type of tag chosen in a large part determines the RFID systems suitability for different types of operations. The passive tag is the simplest version of the RF Tag. A RF Tag is “passive” if it is un-powered, that is if it contains no internal power source. Passive RF Tags obtain the energy needed to operate by coupling electromagnetic waves emitted by the transceiver/antenna, Figure 16³⁰.

Figure 16: Electromagnetic Principal of Passive RFID Tag Operation



Because they are un-powered, passive tags are generally not re-programmable. Typically they come pre-programmed with anywhere between 32 to 128 bits of information. However, because passive tags are un-powered they do come with some inherent benefits. They are lightweight, relatively inexpensive (generally less than \$1), and have an almost indefinite shelf life. Passive RF tags are currently in use in a wide variety of commercial applications, of which animal tracking devices and store theft-deterrent tags are probably two of the applications most are familiar with. Passive tags are currently being studied and implemented in a wide variety of applications within the DoD logistics architecture.

³⁰ Ibid

The opposite of the passive RF Tag is the active RF Tag. RF Tags are referred to as active when they contain their own internal power source. The internal power source allows the active tag to broadcast its own signal to be picked up by a transceiver; it also allows the tag to be re-programmable. The main drawbacks to active tags are their size, cost, and shelf life. Because active tags must contain a power source, they are considerably larger than passive tags. Because they are more technically complex, they are much more expensive than passive tags. A typical active RF Tag retails for around \$100³¹. And because active tags have an internal power source, usually a battery, they have a definite shelf life. Depending on battery type and size, and tag operating characteristics, the shelf life of active tags usually varies between 2-10 years³². It is the active RF Tags high memory capacity (up to 1 MB) and re-programmability that most interest those involved in DoD logistics. These properties lend active tags to a wide variety of applications involving Total Asset Visibility, or TAV, that will be discussed in the subsequent chapters of this report.

b. Modes of Operation

All RFID systems share the same principles of operation, but because they operate using differing frequencies and power levels, certain systems are best suited for certain applications. Figure 17 shows a table of common RFID operating frequency ranges and some of their common uses³³.

³¹Hozven M., Clark G., "DoD Supply Chain Implications of Radio Frequency Identification (RFID) Use Within Air Mobility Command (AMC)," MBA Thesis, Naval Postgraduate School, Monterey, California. 01 DEC 03.

³² "What is Radio Frequency Identification (RFID)?," [Retrieved from www.aimglobal.org/technologies/rfid/what_is_rfid.htm]. 27 DEC 04.

³³ "RFID, A Basic Primer," [Retrieved from www.aimglobal.org/technologies/rfid/resources/paper/rfid_basics_primer.asp]. 28 DEC 04.

Figure 17: Common RFID Frequency Ranges and Their Associated Uses

Frequency Band	Characteristics	Typical Applications
Low 100-500 kHz	Short to Medium Read Range Inexpensive Slow Reading Speed	Access Control Animal Identification Inventory Control Car Immobilizer
Intermediate 10-15 MHz	Short to Medium Read Range Potentially Inexpensive Medium Reading Speed	Access Control Smart Cards
High 800-950 MHz 2.4-5.8 GHz	Long Read Range High Reading Speed Line of Sight Required Expensive	Railroad Car Monitoring Toll Collection Systems

In general, as with all electronic communications, as the frequency increases, the speed of data transfer increases. Also as the frequency of the signal increases, the ability of the signal to reflect, refract, and penetrate objects decreases; therefore, the higher frequency ranges of RFID readers require line-of-sight visibility for data transfer.

Depending on the type of RF Reader and RF Tag in use, and on local regulations, the power output of an RFID system can be significant. In the United States and Canada some of the high frequency passive RFID systems are allowed a power density of up to 4 watts/meter³⁴. Power densities of this magnitude cause Hazards of Electromagnetic Radiation on Ordnance, Personnel, and Fuel (HERO, HERP, HERF) concerns that are just starting to be addressed by military testing facilities. Following is a quote from a paper concerning HERO and RFID prepared by Naval Surface Warfare Center, Dahlgren Division, Code J52.

“Of the RADHAZ categories, HERO is of the most immediate concern with respect to RFID equipment. The concern for the HERO impact of wireless technologies, including passive RFID devices, is the potential for the RF energy transmitted, intentionally or unintentionally, to couple onto electrically initiated devices (EIDs), resulting in unintended activation of the EIDs. This unintended EID activation can result in either dud ordnance or catastrophic ordnance detonation³⁵.

³⁴ “Draft Paper on the Characteristics of RFID-Systems,” AIM Frequency Forums, AIM FF 2000:001. 01 JUL 00.

³⁵ Johnson, D.M. “Passive Radio Frequency Identification Devices and Hazards of Electromagnetic Radiation to Ordnance,” Naval Surface Warfare Center, Dahlgren Division, Code J52. 28 DEC 04.

Because of their low cost and long shelf life, the DoD is planning on widespread implementation of passive RFID systems in its logistics architecture. Preliminary testing by NSWCDD Code J52 has indicated that passive RFID systems may be safe, with separation restrictions, for HERO SAFE ordnance. However, the space separation necessary for HERO UNSAFE ordnance would be so large that it would likely exceed the operational limit for the RFID interrogator, besides being untenable within the holds of a ship's magazine³⁶.

Until the passive RFID-HERO susceptibility problem can be solved through technological advancements, more than likely an interim system combining low-power passive RFID along with active RFID will need to be used to track HERO susceptible ordnance. Such a system might use a small passive RFID tag on individual ordnance components within a storage container and then a low power passive RFID interrogator/active RFID transmitter on the outside of the storage box to communicate with a shipboard distribution tracking system. When an individual component is removed from the storage box it will pass near the passive RFID interrogator. The RFID interrogator will then pass the information to the active transmitter, which will in turn pass the information to the shipboard distribution system. Through this method the shipboard distribution system will be able to maintain an up-to-date inventory of all the storage containers on the ship. Taking the process one step further, the shipboard distribution system can communicate via satellite with CONUS distribution systems, and as certain supplies reach threshold levels, an automatic resupply will be triggered.

c. Current DoD Utilization

The active/passive combination is one of the configurations currently being studied for use within the DoD logistics architecture. DoD investigation into the uses of RFID in the DoD logistics architecture began in early 1997. At that time the Deputy Under Secretary of Defense for Logistics and Material Readiness (DUSD (L&MR)) established the DoD Logistics AIT Task Force. The mission of this group was to develop a CONOPS for the implementation of automated identification technology (AIT) into the DoD logistics architecture³⁷. The output of the AIT task force recommended a variety of technologies for use within the DoD, one of which was RFID.

³⁶ Ibid.

³⁷ Deputy Under Secretary of Defense (L&MR), Automatic Identification Technology Task Force, 07 JAN 97.

Initial implementation of RFID technology began to occur in earnest during the early days of Operation Enduring Freedom/Operation Iraqi Freedom (OEF/OIF). To help keep track of the logistics pipeline during these large-scale operations the United States Army began to outfit its shipping containers with active RFID technology³⁸. They also outfitted key-shipping nodes with RFID transponders, thereby setting up a worldwide grid to help them keep track of their shipping containers. This experiment has worked so well for the Army that they are now studying how to incorporate RFID technology into smaller size loads, again working toward the goal known as Total Asset Visibility (TAV).

The DoD, following the recommendations of its AIT task force, observing the success of the Army's program, and watching the widespread implementation of RFID in the commercial logistics industry, has begun to issue instructions mandating the use of RFID technology in DoD logistics practices. Under current regulations all DoD supplies of pallet size or greater, or value in excess of \$5000 will need to be outfitted with RFID tags by their manufacturer prior to input into the DoD logistics pipeline, before the year 2007³⁹. The DUSD (L&MR) is currently working with major DoD suppliers, and RFID technical experts to lock down a common RFID architecture to implement when the mandate becomes effective. The common architecture is still being debated and has not yet been finalized at this time. As mentioned in the RFID Modes of Operation section of this document, various configurations of RFID systems have different strengths and weaknesses when it comes to operation within the logistics pipeline. It is quite possible that different systems will initially be adopted to meet various needs, with commonality improvements occurring as the differing systems are used within the logistics architecture.

d. Concept of RFID Operation Within the JMIC System

The initial RFID configuration within the JMIC system of logistics containers is still being defined. The prototype JMIC container built by PHS&T does not contain RFID capability, although all of its designers agree that RFID technology is something that will have to be included in the JMIC container system in order to make it a viable logistics transfer platform.

³⁸ Deputy Under Secretary of Defense (L&MR), "DoD RFID Background," [Retrieved from www.acq.osd.mil/log/logistics_materiel_readiness/organizations/sci/rfid/rfid_background.html]. 05 JAN 05.

³⁹ Ibid

The RFID configuration that seems to make the most sense within the JMIC system involves a combination of active and passive RFID systems. Passive RF Tags, because of their low cost and long shelf life, could be used to mark individual pieces of equipment or supplies placed within the JMIC containers. On the outside of the JMIC container a low power passive RF interrogator combined with an active RF transmitter could be used to keep track of the inventory levels of supplies within the box. As supplies were removed from the JMIC they would pass by the passive RF reader, the reader along with the active transmitter could then pass the inventory information to the shipwide distribution system and from there onto a global logistics database.

A system such as described above would have a variety of benefits over using a completely active or passive RFID configuration. Using an entirely passive RFID system with JMIC would require high power RF interrogators and transmitters and this would raise HERO concerns, especially since JMIC is initially being considered as a platform for ordnance transfer. An entirely active RFID system would either be prohibitively expensive, if all supplies were outfitted with active RF Tags, or would have gaps in RF coverage if only the containers were marked with active RF Tags (much like what the US Army is doing today). Using a combination of active and passive systems allows the proposed JMIC configuration to avoid coverage gaps within the container, maintain a relatively low cost by using mainly low-cost passive RF Tags, and ameliorate HERO concerns by not having to use high power passive RF interrogators to read the passive tags within the JMIC containers.

2. Container Blast Hardening

a. System Components

Blast hardening is a reference to the ability of a container to withstand the effects of an explosive blast. Events such as the downing of Pan American Flight 103 by an explosive blast have demonstrated the need for blast hardened shipping containers in commercial airlines, and has spurred a lot of the research that is currently ongoing in this area. The military tends to have a slightly different need and requirement for blast hardening. Because the United States military has to transport ordnance around the globe as part of its daily operations, blast hardened containers are used to help increase the stowage density of material transported and prevent sympathetic detonation of ordnance.

Blast hardening of containers is accomplished a myriad of different ways. Most systems are using high strength materials (steel, Kevlar, titanium, etc.) in structurally strong configurations. Along with high strength materials most blast-hardened containers will contain some method or material for absorbing energy. Examples range from simple plastics like polystyrene to complex composites arranged in special configurations.

The overriding goal of any blast-hardened container is to contain the effects of an explosive blast, both the concussive wave and any shrapnel. In commercial airliners this is done to prevent catastrophic damage to the aircraft, in military ordnance shipping containers it is done to prevent sympathetic detonation of ordnance should an accident occur.

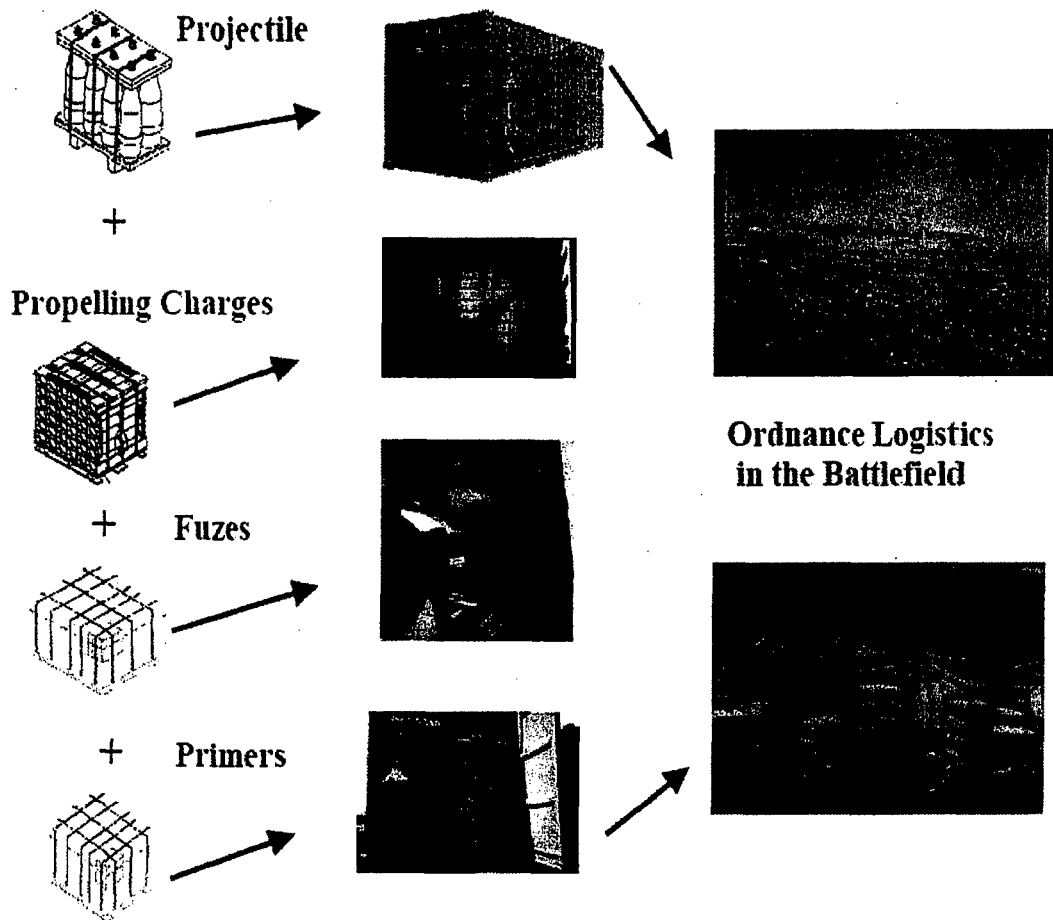
b. Current DoD/JMIC Applications

Today United States Military ordnance is shipped worldwide under a strict regulatory code. In general ordnance is packaged together using two criteria, one of which is its net explosive weight (NEW) or the equivalent amount of TnT the explosive would be equal to if it were to detonate. The other criterion is the ordnance's volatility or susceptibility to some sort of unplanned external shock (thermal, electromagnetic, or physical, etc.).

The restrictions often cause ordnance to be packed in inefficient configurations for shipping, only later to be reassembled at forward operating stations. For a howitzer charge these restrictions mean that the propellant charge, explosive warhead, and detonating fuses all need to be shipped in separate containers. Not only do they have to be shipped in separate containers, the containers themselves have to be separated within the ship's magazine. These restrictions

lead to lower stowage density aboard ship, and a lot of excessive packaging material. The biggest problem tends to be at the final assembly point. Because the staging areas at most forward operating bases tend not to be overly well organized (reference [Figure 18](#)) it is often the case that an assembler, looking to put together howitzer charges for the battlefield, will only be able to find one or two of the multiple different boxes of equipment he needs to assemble the final charge⁴⁰.

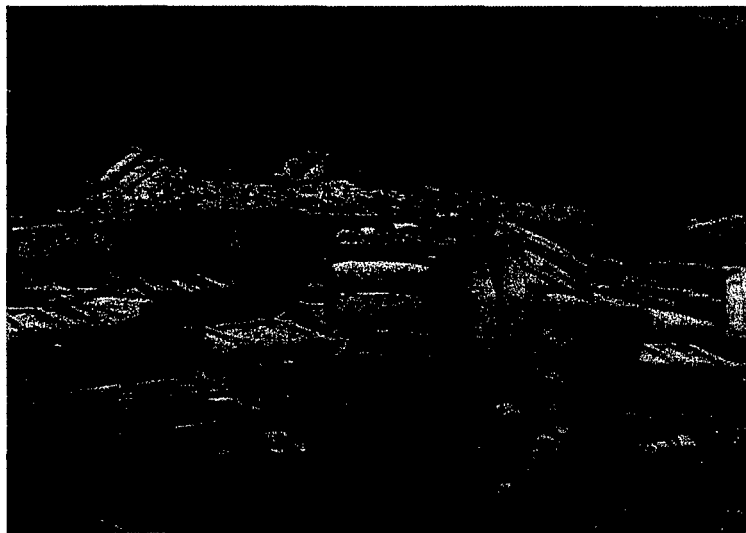
Figure 18: Current Method of Shipping All-Up-Round 155mm Howitzer Charges



⁴⁰ "Joint Modular Intermodal Container," Business Case Report. NSWCIHD, Detachment Earle, Packaging, Handling, Storage, and Transportation Center. 20 FEB 05

Repeat situations like this over a period of weeks and eventually what happens is the logistics laydown area becomes unorganized chaos, where no one can find all the parts he needs to assemble a final component. Eventually what happens is new material is ordered, even though inventory levels show enough material should already be on-hand, to replenish misplaced stock. This unnecessary reordering becomes a large efficiency and cost drain on the supply chain. Figure 19 shows a better view of how unorganized some of these forward ordnance logistics areas can become⁴¹.

Figure 19: Picture of Forward Ordnance Logistics Laydown Area During OIF

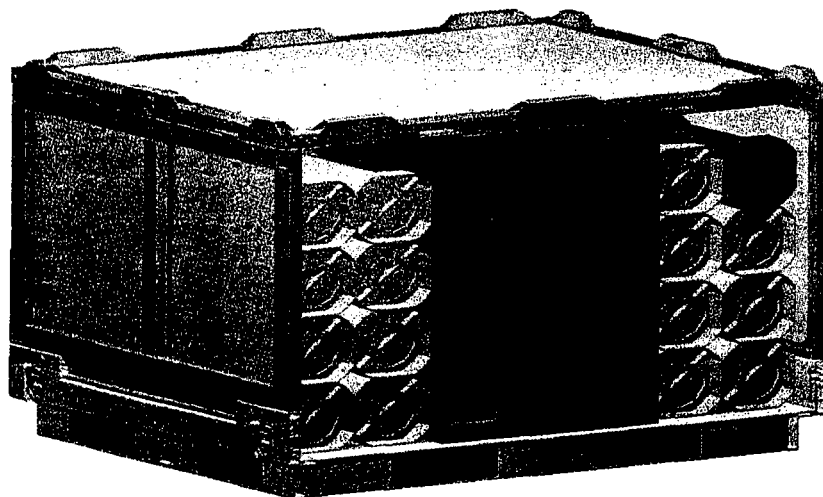


One of the aims of JMIC is to change the way logistics is conducted in the forward logistics operating areas. Through the use of blast hardening technology to goal is to allow JMIC to carry all the components of certain ordnance systems, Figure 20 gives an example⁴².

⁴¹ Ibid

⁴² JMIC Concept Presentation. Brief given by Naval Packaging, Handling, Storage and Transportation Division. 07 DEC 04.

Figure 20: JMIC Loaded with all Components for 155 mm Howitzer Shells



Blast hardening technology would allow the warheads, propellant charges, and fuses all to be packaged in the same JMIC container. Take for example the fuses. Fuses are the most volatile component of any ordnance system. In Figure 20 the fuse container is the red container in the upper right hand corner of the JMIC. In normal break-bulk ordnance packaging the fuses would have to be loaded in a separate container and stored in a different magazine from the propellant charges and warheads. But, if the fuses could be contained in blast hardened packaging in such a way that even if they were to detonate they would not cause sympathetic detonation of the other ordnance, then they could be packaged in the same container as the other components of 155 mm howitzer shells.

By allowing ordnance to be packaged in this way you would achieve greater efficiency in the supply chain. Because the ordnance could be packaged with a greater stowage density than before, ships and aircraft that were transporting ordnance could carry more. And, because ordnance would arrive to the forward logistics base with all components in the same container there would be less chance for certain components to become misplaced, and less unnecessary reordering of supplies, which in effect would also serve to raise the apparent supply chain capacity.

NSWCIHD-Detachment Earle, PHS&T, gave a dramatic example of the increased packing density allowed by blast hardening in their business case analysis for the JMIC system. Figure 21 lists some of the small ordnance components of a typical CV/CVN ordnance loadout⁴³.

Figure 21: Example of Small Ordnance Components in Typical CV/CVN Loadout

Description of Commodity	No. of Rounds	No. of Boxes	Dimension of the Box
Detonating Cord Connectors	3000	1	6"L X 6"W X 8"H
38 Cal Cartridges	2400	2	14.69"L X 10.31"W X 8.62"H
7.62 MM Cartridges	4000	4	14.70"L X 12.44"W X 7.13"H
9MM Cartridges	12000	6	14.44"L X 12.53"W X 8.12"H
Detonating Cords	8000	4	36.08"L X 32.0"W X 24.0"H
Blasting Fuzes	8000	2	29.0"L X 22.0"W X 17.0"H
Detonating Cords	4000	2	21.08"L X 14.75"W X 18.40"H

Under current ordnance packaging guidelines the above munitions are packaged in 21 individual boxes, and the boxes cannot be packaged together. Utilizing blast-hardening technology the same munitions could be transported in two standard sized JMICs, leading to a drastic decrease in material handling requirements, dunnaging for stowage, and ultimately manpower in the logistics pipeline.

A problem with the above scenarios is that the United States Navy logistics system typically does not operate with unit sized loads. Customers do not often order a whole container of ordnance, but instead incremental orders to restock inventory levels. It could be inefficient to use a unit container system such as JMIC to deliver these small incremental loads.

An example of the unit load conundrum is presented in Figure 21. Even though all the items in Figure 21 could be stuffed into two individual JMICs, there would never be a need to do so. There is no single customer who would ever order such a container of supplies, not only that but some of the supplies mentioned have restrictions under OPNAV 5530/13C (Department of the Navy Physical Security Instruction for Conventional Arms, Ammunition, and Explosives) that would prevent them from being stored together or in unguarded areas⁴⁴.

⁴³ "Joint Modular Intermodal Container," Business Case Report. NSWCIHD, Detachment Earle, Packaging, Handling, Storage, and Transportation Center. 20 FEB 05

⁴⁴ Conversation with Mr. Tom Clevenger, CLF Ammunition Operations Officer, Sealift Logistics Command Atlantic. 07 APR 05.

3. Heavy UNREP Capability

JMIC in its current proposed configuration has a fully loaded weight of approximately 3000 lbs per container. Three-thousand pounds is well within the current STREAM UNREP capability and JMIC could be used with this system effectively. However, using JMICs in this matter will not improve UNREP material transfer speeds, as a typical JMIC container has about the same loading as a conventional pallet. In order to really UNREP JMICs in their most efficient configuration the United States Navy needs to implement Heavy UNREP capability. By allowing transfer of up to 12,000 lbs at sea you would enable the most efficient feature of a JMIC system. JMIC containers are designed to be coupled/decoupled from other JMIC containers rapidly. If the US Navy had an UNREP system that allowed for the transfer of multiple JMIC loads, through the use of UNREP skids, or top-loading capability then UNREP material transfer speeds could increase dramatically.

4. Shipboard Smart Warehousing Capabilities

One of the main drivers for adopting a standard sized logistics package system is to enable the use of automated warehousing, also known as "smart warehousing", technology. By allowing for the automated stowage and retrieval of supplies "smart warehousing" gives rise to large savings in manpower costs, and potential increases in shipboard stowage density. In reality the automated warehousing and standard sized packaging systems, such as JMIC, have a symbiotic relationship. Automated warehousing does not function well without a standard packaging interface, and the efficiency improvements incurred by using a standard packaging system for logistics transfer are not maximized unless a "smart warehousing" system is used.

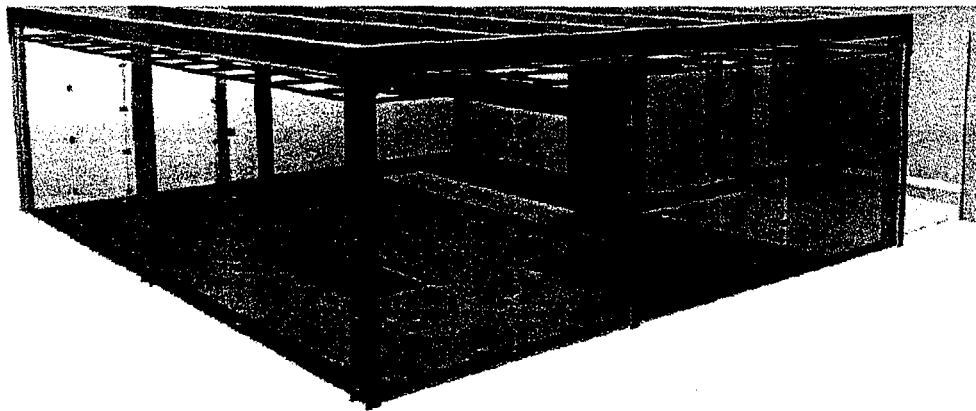
Automated warehousing has been used in large commercial distribution centers for many years. However the technical difficulties faced when adopting some of these commercial land-based systems for shipboard use are difficult and costly to overcome. Only recently has the Navy been seriously investigating the means of incorporating automated warehousing systems into its ships, and as of right now the programs the Navy is investigating are primarily focused on the weapons magazines in some of its larger classes of ships, although systems have been designed to handle other classes of supplies as well.

a. Automated Ordnance Handling Systems

NAVSTORS, or The Naval Stowage and Retrieval System, is a shipboard automated warehousing system currently under development by Naval Surface Warfare Center, Carderock Division, Ship Service Engineering Station, (NSWCCD-SSES), under sponsorship from Program Executive Office, Carriers (PEO-Carriers). Its primary focus is the development of an automated ordnance warehousing system for aircraft carrier weapons magazines. The system is being designed as a retrofit for CVN-68 class ships, and as a new design to be included with the development of CVN-21.

The core capability of the NAVSTORS system is a x-y axis indexing, linear motor direct drive flooring system, Figure 22⁴⁵. Much like a child's slide puzzle, this system allows any individual piece of the magazine's deck to be moved to any position within the magazine, simply by leaving one space of the decking open for indexing.

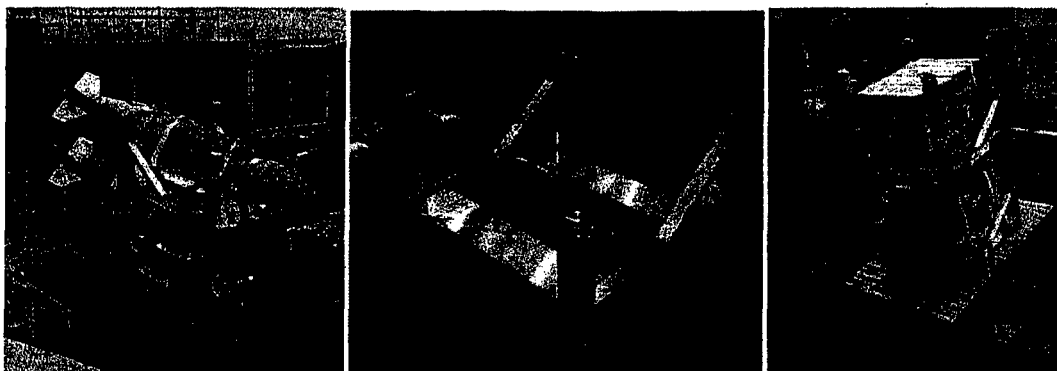
Figure 22: NAVSTORS X-Y AXIS Indexing Flooring System



To date NAVSTORS has been developed specifically for ordnance, using a standard packaging system known as the Standard Payload Interface (SPI), Figure 23, but the system could easily incorporate a JMIC like system, and be used in general storage areas if the development funding were provided⁴⁶.

⁴⁵ McCammon T., "Sea Base Roadmap Phase II Operations and Technology Initiatives," NSWCCD-SSES. 19 FEB 05.

Figure 23: Standard Payload Interface



Following an ordnance package through a notional UNREP evolution will help the reader gain an understanding of how the NAVSTORS system works⁴⁷:

1. Utilizing heavy UNREP capability a 10,000 lb load of iron bombs encased in a SPI arrives at the kingpost (Attachment point for UNREP equipment) in the CVN's hangar bay, where it is subsequently lowered onto a omnidirectional vehicle (Figure 24).
2. The omnidirectional vehicle moves the load to one of the CVN's hangar bay weapons elevators (Figure 25).
3. Once the weapons elevator arrives at the magazine, the omnidirectional vehicle carries the bomb load to an open direct drive deck tile at the front of the x-y interface.
4. A top-lift crane then removes the bomb load from the omnidirectional vehicle and places it on the open deck tile.
5. The deck tile is then indexed into the magazine using direct drive linear motors. Once the deck tile reaches its correct position, the linear motors de-energize and an automatic screw type mechanical interface is manipulated to lock the bomb rack down to the deck.
6. As the process is repeated all the available deck tiles are filled. Bomb racks are then placed in stacks and locked to one another using the same screw-type mechanism. Eventually you arrive at a full magazine, with very high storage density, and using a minimal number of supervisory personnel to observe the automated system, Figure 26.

⁴⁶ McCammon T., "Technology Insertion Options and Recommendations," NSWCCD-SSSES. 19 FEB 05.

⁴⁷ Ibid.

Figure 24: 10,000 lb Bomb Load Being Lowered onto Omnidirectional Vehicle

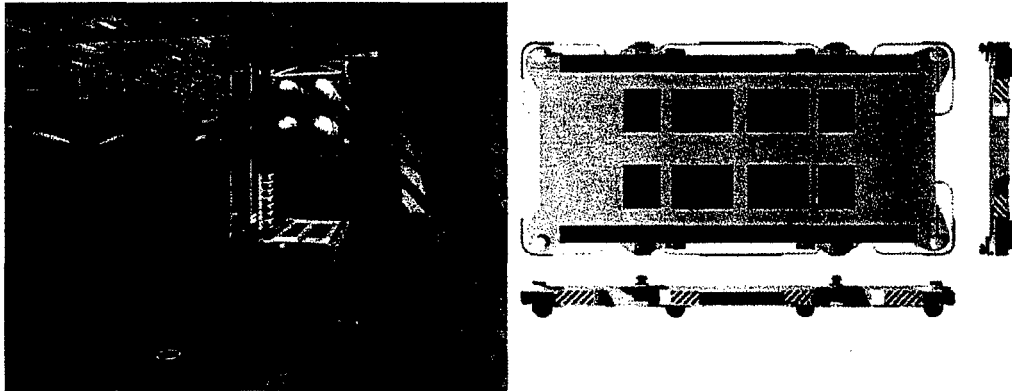


Figure 25: Omnidirectional Vehicle Traverses to Hangar Bay Weapons Elevator

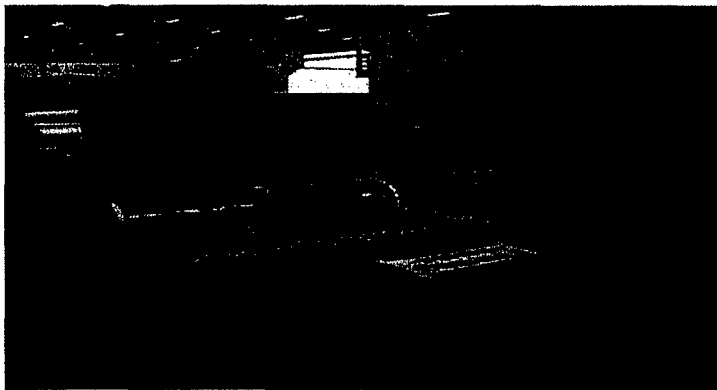
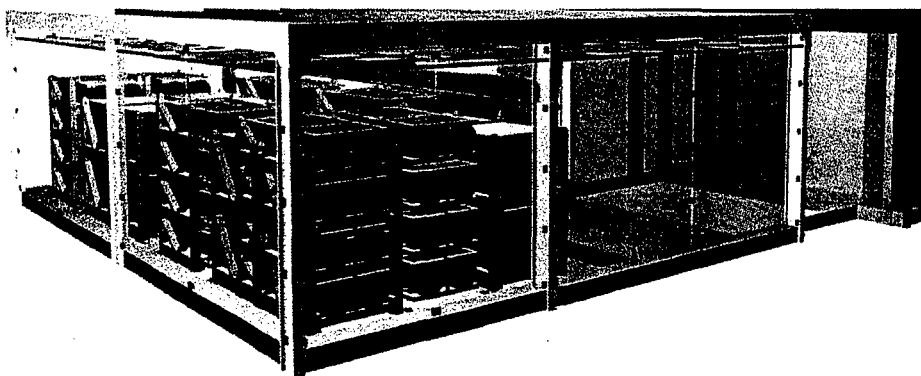


Figure 26: Magazine Filled Using NAVSTORS System



It is not too difficult to imagine JMICs filled with a variety of supplies replacing the SPI encased iron bombs in the NAVSTORS system. On future large-deck ship designs elevators could service automated storerooms, allowing for the same concept of operations as described by NAVSTORS above, in fact such a system is being proposed as part of the CVN-21 design.

b. Automated Storerooms

The main problem with current ship class storerooms, from an automated warehousing perspective, is that they tend to be odd-shaped and located in areas along the hull, where horizontal deck space is minimal compared to overall storeroom volume. In general most current Naval ship classes have very few storerooms that would be suitable to convert to an automated warehouse. Figure 27 shows an example of a typical Naval combatant frozen storage⁴⁸. Naval combatants also tend to use all available space as functional space, so most current ships do not have center-of-the ship, square, flat spaces available for conversion to an automated storeroom, not without a loss in current ship functionality or a major ship redesign and retrofit.

It is unlikely that automated warehousing concepts will find their way onto current Naval combatant ship classes. What is likely is that current Naval ship classes being designed today will incorporate some type of automated warehousing of stores into their designs, as a method of reducing ship's crew size and overall ship total ownership cost (TOC).

Because of a lack of commercial application, shipboard smart warehousing technology has not been widely developed. The system proposals that are available are in the early development phase and tend to be an adaptation of commercial land-based systems, to leverage off commercial-off-the-shelf (COTS) technology.

⁴⁸ Email. Mr. John Cavalieri, NSWCCD-SSES. 28 FEB 05.

There are a couple of major hurdles to overcome when adapting land-based smart warehousing technology for use at sea. One hurdle is that land based systems tend to require a large operational footprint, something not always available in the tight confines of a ship's hull. The other major hurdle is that most land-based systems tend to use the force of gravity to secure items placed within the warehouse storage racks. Obviously a ship at sea undergoes motion, sometimes violent motion, and gravity cannot always be counted on to maintain items in position. Designing secure-for-sea systems to tack onto commercial automated warehousing technology is often not trivial, especially since there is little development funding for such systems besides the military.

Figure 27: Most Current Ship Storerooms Unsuitable for Automated Warehousing Space

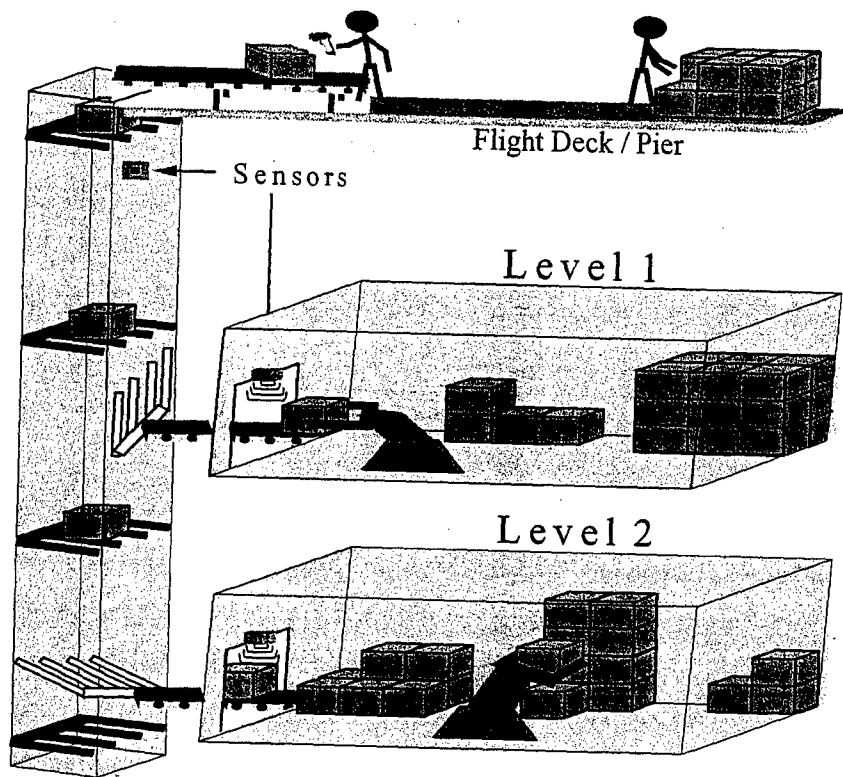


While all the systems that have been designed for shipboard use are still in the early stages of development, the system designs do tend to fall into two categories. One category is the systems that are designed to handle supplies in pallet size configurations. These systems typically closely resemble commercial based systems, albeit usually using a much smaller footprint. Most of these systems are being designed with the premise being included on future naval ship designs, as the retrofit of these systems onto existing naval platforms would be extremely difficult and expensive, if possible at all.

The second category of automated warehouse designs for naval ships tend to be designed around improvements to the package conveyor systems currently found on most US Navy ships. These designs typically involve the use of computer controlled package conveyors with robotic arms stationed at each trunk door, Figure 28⁴⁹. The main idea of these designs is to leverage smart packaging technology (i.e. RFID) to enable removing the human element from the loading/unloading/operation of the package conveyor. Some of these systems are also designed with automated storage and feeder systems on either side of the conveyors, dependent on the space available on the ship class being designed for. Most of these systems are designed around a retrofit application to an existing naval ship class. As much of the technology associated with these systems is still emerging, especially when being considered for operation in a shipboard environment, none of the systems designed has yet to be slated for installation onto an existing platform.

⁴⁹ "Autonomous Mobile Cargo Handling for Carrier Automation," Program Executive Office, Aircraft Carriers. 08 MAR 05.

Figure 28: Smart Warehousing Concept Using Existing Package Conveyor Trunks



C. JMIC CONCEPT OF OPERATIONS

The preceding sections of this thesis have served to increase the reader's familiarity with the United States Navy's logistics transport and transfer methods, some emerging technologies in the logistics field, and the proposed design for a new logistics transport system, the Joint Modular Intermodal Container. All of the work described in the preceding sections was either background material or commentary on work being performed by others. The main focus of the research for this thesis was to determine a proposed concept of operations for the JMIC system that would operate most efficiently in the current and future proposed United States Navy, and indeed United States Military, logistics architecture.

1. Loading JMICs Ashore

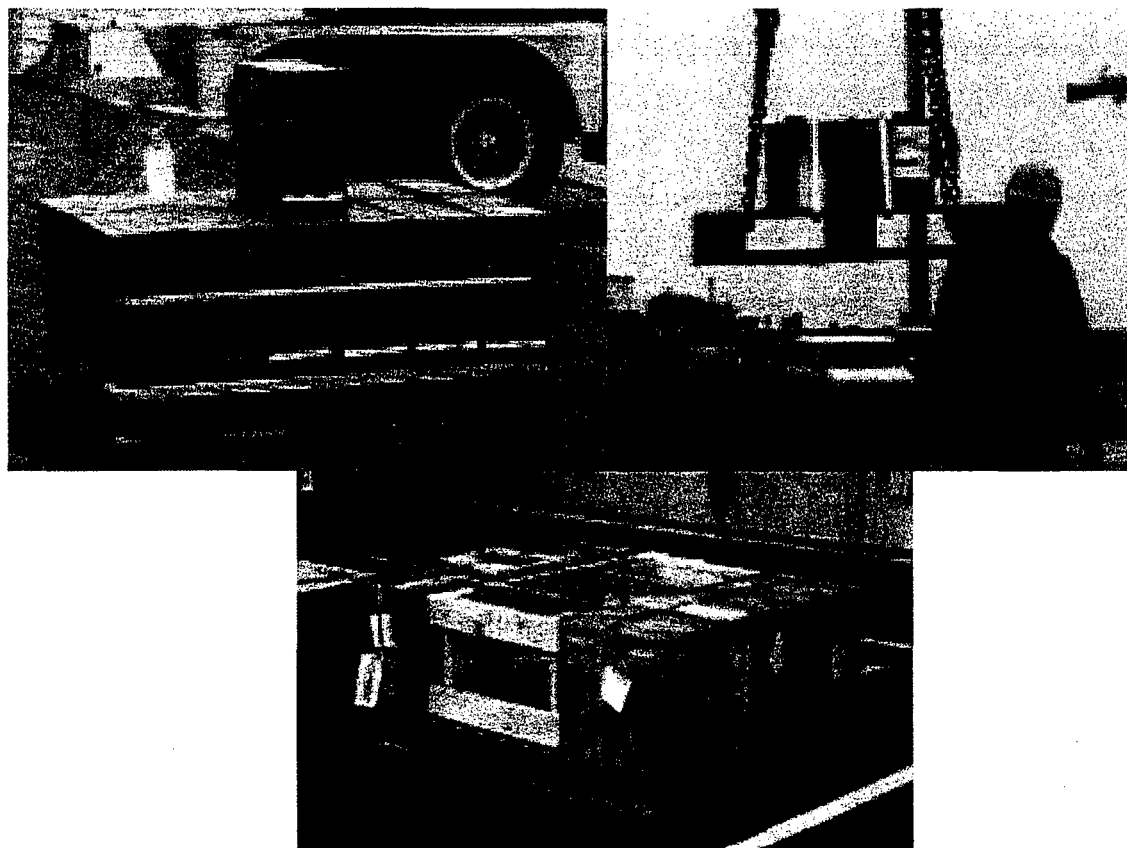
The current US Navy shore based logistics practices were covered in some detail in Section I.A. of this thesis. The current practice of loading goods onto logistics ships using wooden pallets is inefficient; pallet loads are not uniform, they require separate bracing, they require extensive dunnaging to be secured for sea onboard ship. Wooden pallet loads often underutilize the capacity of their handling systems because dissimilar sized supplies prevent loading a pallet to its full capacity. Figure 29 shows some examples of inefficient pallet loads prepared to be loaded aboard ships⁵⁰.

There are five distinct stages to loading palletized goods aboard a ship:

1. Breakout – Removing pallets from warehouse storage
2. Staging – Moving pallets from warehouse to pier, positioning pallets on pier in preparation for loading.
3. Loading – Moving pallets from pier to the ship.
4. Storage – Moving pallets from ship's loading area to its storage holds.
5. Secure – Securing pallets for sea in the ship's holds.

The problem with inefficient palletized loads is that they have a compounding effect on the loading cycle. Each of the stages above involves a separate handling of the palletized supplies. Therefore, a pallet not loaded to full capacity is not only inefficient at one material handling point, but at five. Not only that, but the inability of some pallets to be stacked together leads to a larger warehouse space, pier staging area, ship laydown area, and ultimately ship's hold to store the same amount of less densely packed material.

Figure 29: Inefficient Wooden Pallet Loads



Because JMIC is a program still in the early stages of development, it is not yet known if its packing density will exceed that of the nominal wooden pallet loads. However, it can be assumed that JMIC will have efficiency improvements in its material handling characteristics, due to its standard handling interfaces and container sizes, and these efficiency improvements will translate into budget savings for the United States Navy.

A T-AOE loading out at a Naval Weapons Station could be one example where large cost savings could be incurred by using a JMIC system. A typical T-AOE ordnance loadout for a 6-month deployment would consist of approximately 2,000 individual pallets or containers of ordnance⁵¹. Loading times for 2,000 “lifts” would vary depending on which Naval Weapons Station the T-AOE was using, because each weapons station has a unique means of loading ships

⁵⁰ Joint Inter Logistics Working Group Presentation. NSWCIHD PHS&T. 08 DEC 04.

⁵¹ Email. Mr. Dennis Costa. Naval Ordnance Logistics Supply Center. 10 FEB 05.

based on their differing infrastructure. Assuming the ship was loading ordnance at Naval Weapons Station Indian Island in Washington State the typical load rate is about 500 lifts/day, which translates into 4-5 days pierside for a complete loadout⁵². Now if a JMIC system could increase the material handling speed by 25%, the Naval Weapons Station could load 625 lifts/day and the T-AOE might only need 3-4 days pierside to load the same amount of material. That translates into 1-2 additional operational days for the ship. If you consider that the US Navy owns these ships and pays for them whether they are operational or not, every day the ship is available to perform an operational mission is one day the US Navy does not need to obtain from another similar vessel.

The nominal daily cost for a T-AOE CLF ship is \$85,000/day⁵³. Considering the US Navy operates four of these vessels, and six smaller crewed T-AE's, the saved operational days can translate into significant savings, or increased operational flexibility to the war planner.

Pierside time at a Naval Weapons Station is also a commodity to be considered. The United States Navy only has four Naval Weapons Stations for loading ships. Pierside time at these facilities is also very limited, and any improvements in loading efficiency would also serve to greatly increase the capacities of these valuable facilities.

If actual testing shows JMIC to improve on both material stowage density and material handling speeds vs. nominal wooden pallets and specialized ordnance carriers, then the JMIC system has the potential to dramatically increase the capacity of Naval Weapons Stations, as well as the operational availability of Combat Logistics Force ships. Both of these factors will help to offset the increased cost of a JMIC system vs. today's standard pallets and specialized containers.

⁵² Ibid

⁵³ "NAVY SHIPS, Turning Over Auxiliary Ship Operations to the Military Sealift Command Could Save Millions," United States General Accounting Office. GAO/NSIAD-97-185. AUG 97. [Retrieved from www.gao.gov/archive/1997/ns97185.pdf]. 13 JAN 05.

2. JMIC Compatibility With Current United States Naval Fleet

One of the key parameters to consider when adopting any new logistics system such as JMIC is the compatibility of that system to the current US Naval Fleet. The United States Navy currently operates 290 ships, none of which was designed for a standard containerized logistics system⁵⁴. The cost associated with retrofitting all these ships, if even possible, to ideally handle a system such as JMIC would be enormous. Because it is not economically possible to retrofit all the US Navy's existing platforms, it is important to gain an understanding of the current ship classes that could effectively use JMIC with little or no retrofit.

There are a few functions a ship needs to perform to use the JMIC system in an effective manner. First of all the ship needs to be UNREP capable, either using STREAM CONREP or VERTREP in order to transfer JMICs at sea. This requirement immediately eliminates some of the US Navy's smaller, specialized ship classes such as MCM, MHC, and PC. Secondly the ship needs to have elevators capable of accommodating a fully loaded JMIC. For the ships that have elevators this is normally not an issue, as the elevators were sized to carry ordnance loads on wooden pallets that were close to the same dimension, and weighed as much or more as a fully loaded JMIC. Finally in order for the ships to accept JMICs carrying supplies other than ordnance, the ships need to have storerooms of sufficient size to hold a JMIC that are either co-located next to a weapons elevator or accessible from a passageway of sufficient dimension to pass a JMIC through. This final requirement is currently not well met in the United States Naval Fleet.

The following sections contain commentary on the applicability of JMIC with some of the current US Naval Ship classes; all information was gathered from ships' general arrangement drawings:

⁵⁴ [Retrieved from www.navy.mil]. 16 FEB 05.

a. Surface Combatants

The United States Navy currently operates three classes of surface combatants of sufficient size to be considered for use with a JMIC type intermodal container system. All three classes could use JMIC to carry ordnance, replacing the specialty ordnance pallets in use today. Two of the three classes, FFG-7 and DDG-51, could use JMIC for general supplies with varying efficiency. Both the FFG-7 and DDG-51 would have to have a certain amount of ship alteration to make them compatible for JMIC sized loads of general supplies.

A problem with adapting surface combatants for JMIC use is that because of their small crew sizes (relative to larger naval vessels) these ships do not consume massive amounts of general supplies when they are out to sea. Therefore, because the logistics resupply of these ships is relatively minor, when compared with some of the larger vessels the US Navy operates, any efficiency gains incurred by using the JMIC system for general supplies will have a smaller noticeable effect. The smaller logistics needs of these ships will be an issue when determining if it is cost effective to retrofit the ships for JMIC use.

FFG-7

For a small combatant FFG-7 is set up relatively well to handle a limited amount of intermodal containers. The ship has a relatively large (6 ft) passageway leading from the flight deck to amidships and a large (8 ft) athwart ship passage way at amidships. Both of these passageways give access to a centrally located elevator (4000 lb capacity) that is capable of handling a JMIC sized container. The elevator has access to a central storage area on the ship's second deck, within the storage area there are three sizeable storage spaces for dry provisions (16 X 24 ft), frozen goods (7 X 14 ft), and chilled provisions (7 X 14 ft). The doorways to the storerooms are currently too small to pass a JMIC container through, but could possibly be widened if such a system were proposed for use with the FFG-7⁵⁵.

⁵⁵ NAVSEA Drawing FFG-7-801-4661188. SEP 76.

DDG-51

DDG-51 is currently not well suited to handle an intermodal container system for its logistics needs. The ship does have some centrally located storage capacity for dry, freeze, and chilled goods around frame 220, but the dry and chill storerooms have somewhat disjointed shapes because of obstructions. The freeze storeroom is rectangular shaped and is of a decent size (16 X 20 ft) for accommodating JMIC containers. The storerooms are accessed by a central storage landing area, but their doors are currently too small (3 ft) for JMIC size loads. Another problem is the storerooms are currently only served by a package conveyor which is not capable of handing a JMIC container. For the central storerooms to be made intermodal container capable their doorways would have to be widened and the package conveyor would have to be replaced with a larger elevator (in the process a fair amount of interference would have to be removed). Deck strengthening of the storerooms and landing might also have to be performed depending on the loading factor of the JMIC containers.

Another possibility for JMIC storage in DDG-51 is the aft laundry space located at frame 410. The space is large (22 X 32 ft) and located directly under the flight deck. In order to make the space work the laundry would have to be moved to another location within the ship and an elevator would have to be installed in the flight deck that would not interfere with helicopter operations. A downfall of this space would be that it is not centrally located, and supplies stored there would be a relatively long distance from their ultimate point of use⁵⁶.

CG-47

Ticonderoga class guided missile cruisers are not set up well to interact with intermodal container systems. In general most of the storerooms on the ship are small in size and widely disbursed, typically being closely located with the ultimate point of stores end use. Unlike FFG-7 and DDG-51, CG-47 class ships do not have a central hub of ship services but instead have smaller groupings of services, such as galleys, located throughout the ship. CG-47 does have two separate weapons elevators that are capable of handling JMIC sized loads, but the weapons elevators only give access to magazines and the magazine and weapons elevator locations do not lend themselves well to co-locating storerooms in those areas⁵⁷.

⁵⁶ NAVSEA Drawing DDG-51-802-5774035-E. JUN 84.

⁵⁷ NAVSEA Drawing CG-47-101-5384439-AP. JUN 86.

b. Amphibious Ships

United States Naval Amphibious Ships are typically better suited than surface combatants to use a JMIC system effectively. For one the ships are larger and have a primary mission of carrying cargo, namely US Marines and their associated gear. All the amphibious ships the Navy operates have at least one elevator, and at least one elevator always services the ship's cargo areas. All of the ships could store JMICs in the cargo areas they use for Marine gear, especially if the Marines end up adopting a JMIC like intermodal container system for their cargo. Some of the ships have elevators that also give access to the ship's general storerooms and could possibly use JMIC for general cargo. Like surface combatants, all of the amphibious ship magazines are sized to handle weapons in pallet (or JMIC) sized loads.

LPD-17

The Navy's newest amphibious ship LPD-17 is generally quite compatible with a JMIC intermodal container system. The ship has large, rectangular storerooms located just forward of cargo elevator #1 (55 m aft of fwd perpendicular) that are serviceable by the cargo elevator (12,000 lb capacity). The doorways on the storage rooms would have to be widened to pass JMIC sized loads. In addition JMICs could also be stored on the ship's cargo decks if carrying Marine gear. The ship also has storerooms located further up in the bow, but these storerooms are only accessible via package conveyor and are not shaped well for intermodal container storage⁵⁸.

LPD-4

LPD-4 class ships have only one large capacity cargo/weapons elevator (16,000 lbs). The elevator does give good access to the general cargo storage areas of the ship, allowing for adequate JMIC storage. The ship's freeze and chill storerooms are located just forward of the cargo storage area, and are primarily served by a package conveyor. The doors of the storerooms could be repositioned and widened to allow for JMIC storage, but the storerooms themselves are somewhat oddly shaped and not very compatible for pallet sized loads⁵⁹.

⁵⁸ NAVSEA Drawing LPD-17-802-6337252. JAN 95.

⁵⁹ NAVSHIPS Drawing LPD-4-800-2502158. MAR 66.

LSD-41/49

LSD-41 class ships have an 8,000 lb capacity cargo/weapons elevator located near the bow of the ship (frame 27), it is also co-located with a large size package conveyor (6 ft X 6 ft). Both the elevator and package conveyor can service the ship's dry, freeze, and chill storerooms on the 2nd deck and freeze storeroom and magazine on the 3rd deck. All storerooms would have to have their access doors widened in order to accept JMIC sized loads. The ship's package conveyor is not configured to handle palletized supplies. The cargo elevator also services the ship's Marine cargo area.

LSD-49 class ships are configured much the same as the LSD-41 class, with the exception being the ship's Marine cargo area is much larger at the expense of a smaller well deck. JMIC compatibility with this class of ship would be the same as LSD-41, except more storage capacity in the Marine cargo area⁶⁰.

LHA/LHD

Due to their primary mission as aircraft support platforms both LHA and LHD class ships have a large number of elevators (LHA-10, LHD-6). The cargo/weapons elevators only service the ship's magazines and Marine cargo areas, both of which are quite large (>140,000 ft³). Both class of ship have freeze/chill/dry storerooms serviced only by package conveyor.

In the LHA class the passageways leading to the entrances of these storerooms are too narrow (4 ft) for JMIC sized loads. It is unlikely that JMIC containers could effectively be used for provision storage on these platforms without extensive, costly, ship alteration to make the provision storerooms more accessible⁶¹.

LHD class storerooms are also normally accessed via package conveyor; however, the ship's chill storeroom does share a bulkhead with the ship's vehicle deck, and an opening could conceivably be installed in this bulkhead to allow JMIC passage into this storeroom⁶².

⁶⁰ NAVSEA Drawing LSD-801-4801081-E. APR 90.

⁶¹ NAVSHIPS Drawing LHA-845-4524347. OCT 78.

⁶² NAVSEA Drawing LHD-101-7499001-A. APR 03.

b. Aircraft Carriers

Despite being very large ships with many elevators all of the US Navy's current aircraft carriers are not easily compatible with JMIC intermodal containers. The carriers do have large capacity, uniformly shaped magazines serviced by high-capacity weapons elevators, and are therefore very compatible with JMIC ordnance containers. The problem lies in the ship's storerooms. Most carrier storerooms are accessed through normal width (4 ft) passageways, and are only serviced by package conveyors. There are some storerooms located off of the ship's hangar bay that could be used for general supply JMIC storage, but the storage capacity of these areas is small when compared to the overall storage capacity of these mammoth ships.

CV-63/CV-67

It is very unlikely the United States Navy would budget to update the logistics systems on its last two fossil fueled aircraft carriers at this stage of their lifetime. The ship's forward storerooms are currently served by a package conveyor but do share a bulkhead with a weapons elevator. It is conceivable that an access could be fashioned from the storerooms to the elevator to allow for JMIC sized loads, but again unlikely due to the age of the vessels⁶³.

CVN-65

CVN-65 does have a large, central storage location on the after portion of its third deck. The storerooms are currently served by what is termed a 'stores elevator', but is in all reality a large package conveyor. The elevators dimensions are of sufficient size (48 X 60 in) that it could possibly be replaced by a pallet conveyor, but a better solution would be to cut a sufficient size access passage between the aft 3rd deck magazine (served by a weapons elevator) and the 3rd deck storage area. This access passage would allow JMIC size containers to be brought from the hangar bay down into the magazine and then passed back into the storeroom. Again, the advancing age of this ship is going to play a factor in any logistics system upgrade planned for the ship. With the implementation of a JMIC system still years in the future it is likely that this ship would not be a candidate for alteration⁶⁴.

⁶³ BUSHIPS Drawing CVA-64-800-1429927-A. SEP 56.

⁶⁴ BUSHIPS Drawing CVA(N)-800-1752010-A. AUG 57.

CVN-68

Nimitz class aircraft carriers are not well suited to use a JMIC system for supplies other than ordnance. Besides storerooms located on the ship's main deck (generally off the hangar bay), the ship does not have any storerooms that would be accessible to a JMIC system. Storerooms not located on the main deck are only accessible via passageway (4 ft), via package conveyor. Unlike CVN-65, the ship's lower deck storerooms are disbursed rather than centralized, and there is no particular location where installing a stores elevator, or cutting a passage in a magazine bulkhead, would enable a large amount of JMIC general storage. The ship does have large, uniformly sized magazines that are well served by weapons elevators and is therefore very compatible with JMIC ordnance containers⁶⁵.

c. Combat Logistics Force Ships

Combat Logistics Force ships are designed to handle their cargo in pallet size configurations. The ships are therefore completely compatible with JMIC containers. The bigger issue with CLF ships is not if they can store and transfer intermodal containers, but the concept of operations on how those containers are employed. This issue is covered in greater detail in Section III.B.3 of this thesis.

The United States Navy's current ship classes, with the exception of some of the CLF ships, were not designed with passageways, conveyors, or decks that could accommodate bringing full pallets, or JMICs, of supplies to the ships' storerooms. In general passageways are not wide enough and/or conveyors do not have a large enough capacity or cubic dimension⁶⁶. Most of the ship classes do have 'work-a-rounds' that would allow them some JMIC compatibility for general supplies, but all would involve a varying degree of ship alteration. The most likely scenario would be for a JMIC like intermodal container system to be adopted by some of the other services, as well as being included in the designs of future warships. If JMIC began to see widespread use in these other areas then back fit of existing ships (that were not at the end of their useful life) would perhaps begin to be considered.

⁶⁵ Email. Mr. Gary Good. Northrup Grumman Corporation. 10 MAR 05.

⁶⁶ Conversation with Mr. John Cavalieri, NSWCCD-SSES. 28 FEB 05.

Figure 30 shows a table of the current ship classes operated by the United States Navy and shows a summary of each ship classes compatibility with a JMIC system⁶⁷.

Figure 30: JMIC Compatibility with Current Naval Ship Classes (>3000 tons)

	# of Elevators	Capacities (1000 lbs) *	JMIC Capable Magazines	JMIC Capable Storerooms	Modifications Needed	Modification Cost	Compatibility After Ship Alt
CVN	9-10	10.5	Y	N	E, P, A	High	Fair
CV	9	10.5	Y	N	E, A, D,	Medium	Fair
LHA	10	10, 12	Y	Y/C	E, P, A	High	Poor
LHD	6	12	Y	Y/C	E, P, A, D	Medium	Fair
LSD-41	1	8	Y	Y/C	A	Low	Good
LSD-49	1	8	Y	Y/C	A	Low	Good
LPD-4	1	16	Y	Y/C	SS	Medium	Fair
LPD-17	2	12, 16	Y	Y/C	A	Low	Good
CG	2	6	Y	N	E, P, A, SS	High	Poor
DDG	1	5.2	Y	N	E, A, SS	Medium	Fair
FFG	1	4	Y	N	A	Low	Fair
AE	6	10.5	Y	N	None	N/A	N/A
AOE	7*	12, 16	Y	Y	None	N/A	N/A

*AOE-6 Class has 1 stores elevator and 1 Stores pallet conveyor, both can accommodate JMIC

Y- Yes, N – No

Y/C – Yes in cargo area of amphibious ship

E – Needs stores elevator installed

P- Passageways outside storerooms insufficient width

A- Access doors to storerooms need widened

D- Access doors need to be installed between storeroom and magazine or cargo deck

SS- Storeroom shapes need to be changed

⁶⁷ "ULT: Platforms, Terminology, and Acronyms," Agile Systems Inc. [Email. Mr. Thomas McCammon, NSWCCD, Code 97]. 16 FEB 05.

3. Using JMICs in Connected/Vertical Replenishment

As discussed in Section I B-C the United States Navy's current methods of conducting connected and vertical replenishment of ships at sea are manpower intensive operations. To help give the reader an idea of how many personnel are involved in these evolutions a brief questionnaire was sent to the Assistant Supply Officers of COMLANTFLT (East Coast) large deck ships (CV, CVN, LHA/LHD). Below is a copy of the questionnaire that went out.

1. How large is your Supply Department? How many of those personnel are directly involved in the UNREP evolution as it is taking place?
2. How many personnel from your Supply Department are normally sourced to work in the hangar bay and on the flight deck during a normal UNREP evolution?
3. How many personnel do you use to handle either paper-based or bar code type accounting during an UNREP evolution?
4. What is the normal size of the working party your ship calls to handle breakdown of pallets and storage of supplies below?

Figure 31 shows an average of the data that came back, broken down by ship class. The actual raw data is available in Appendix A.

Figure 31: Results of Large Deck Ship UNREP Manning Questionnaire

	CV/CVN	LHA/LHD
Size of Supply Department	527	203
# of Supply Personnel Involved in UNREP	158	165
# Work in Hangar Bay	66	122
# Work on Flight Deck	27	15
# Involved in UNREP Accounting	8	7
Size of UNREP Working Party	217	162

Looking at the data presented in Figure 31 a few facts become readily apparent. First of all the size of the Supply Departments on both classes of ship is fairly large. In both cases Supply Department represents about 10% of the ship's crew. The second fact is that UNREP is a manpower intensive operation, at least from the perspective of accounting for and moving supplies around the ship. Personnel stationed in the hangar bay, on the flight deck, or called as part of a working party are primarily used to receive and move material around the ship. Depending on ship class these personnel can account for upwards of 15% of the total ship's crew.

Presuming a JMIC receiving and internal transfer system can be correctly designed and incorporated into future United States Naval Ships, it is the personnel requirements for the receiving, accounting, breakdown, and storage of wooden palletized goods that will most likely be able to be reduced. Considering the average military member costs the DoD around \$90,000 dollars a year there is a large potential for JMIC to reduce overall manpower costs⁶⁸.

JMIC will reduce manpower needs by eliminating the need for paper based accounting (through RFID) and helping to eliminate the need for hangar bay pallet breakdown (through smart packaging). Of course not all of the personnel removed from the UNREP evolution will be able to be removed from the ship, as all these individuals serve other shipboard functions as well. However, UNREP manning reductions could combine favorably with other manning initiatives to lower overall ship manning requirements.

JMIC will potentially have "top-lift" capability that will enable it to be used with automatic stowage and retrieval systems now being proposed for ordnance (NAVSTORS). JMIC has the potential to greatly decrease strike-up/strike down times and increase connected cargo transfer rates, both of which could help lower overall connected replenishment times for ships. Decreased replenishment times would have a cascading effect throughout the United States Navy underway replenishment architecture. Not only would individual ships be able to complete this evolution faster, thereby giving them more "on-station" time to complete their primary mission, but US Navy Combat

⁶⁸ "Military has Great Personnel, but They Come at a Cost," Navy Times. Gannett Publishing, Springfield, VA. 28 FEB 05. pg(s) 15-16.

Logistics Force assets would effectively have more capacity as they would be able to service more ships in a given underway day. Recent CLF ship decommissionings, schedule delays in CLF new construction, and increased worldwide optempo, have greatly stressed CLF capacity. Any effective capacity increases for these busy assets would serve real benefits to the US Navy.

It is currently hard to estimate how many personnel JMIC will be able to remove from the UNREP evolution, or how much JMIC will improve strike-up/transfer/strike-down times, because at this time JMIC is still only a concept with a single developed prototype. Naval Package Handling Storage and Transportation (PHS&T) has been tasked by Office of the Chief of Naval Operations (OPNAV) to develop 16 JMIC prototype containers. The plan is then to use these containers in UNREP evolutions at sea to gain some real world data on JMIC's UNREP improvement capabilities. The current timeline for this testing is in the fall of 2005.

Besides potentially lowering UNREP manning requirements JMIC will also have some additional added benefits over the current practice of shrink-wrapped pallets. JMIC will be considerably more weather resistant than current packaging concepts for general supplies. The sea is a harsh environment and it is not uncommon for supplies staged for transfer on deck to be subject to sea-spray or rain (Figure 32)⁶⁹.

⁶⁹ Email. Mr. John Cavalieri, NSWCCD-SSES. 28 FEB 05.

Figure 32: The Harsh Environment of UNREP at Sea



Characteristics of the JMIC system such as increased strike-up/strike-down/transfer speeds, compatibility with automated stowage and retrieval systems, weather resistant packaging, and reduction in manpower requirements have the potential to greatly alter the United States Navy's underway replenishment operations. What is yet to be determined is if the benefits associated with implementing a system such as JMIC will outweigh the costs of doing so. It will be impossible to make this determination until further development and at-sea testing of the JMIC prototypes is done to help determine some of the actual efficiencies introduced by the system. What is known is JMIC's incompatibility with current US Naval Ships storeroom design is a large detriment to adopting a system that can be used throughout the Navy for all varieties of naval supplies.

4. Using JMICs in Support of Seabasing

Recently the Chief of Naval Operations introduced Sea Power 21, a vision for the future of the U.S. Navy. It is based on three fundamental pillars: Sea Strike, Sea Shield and Sea Base⁷⁰. There are a myriad of proposals for what constitutes a SeaBase, but each proposal has a common theme of enabling rapid intermodal transfer of material and personnel at sea.

Figure 33: Sea Power 21 Notional Sea Base Joint Operating Area

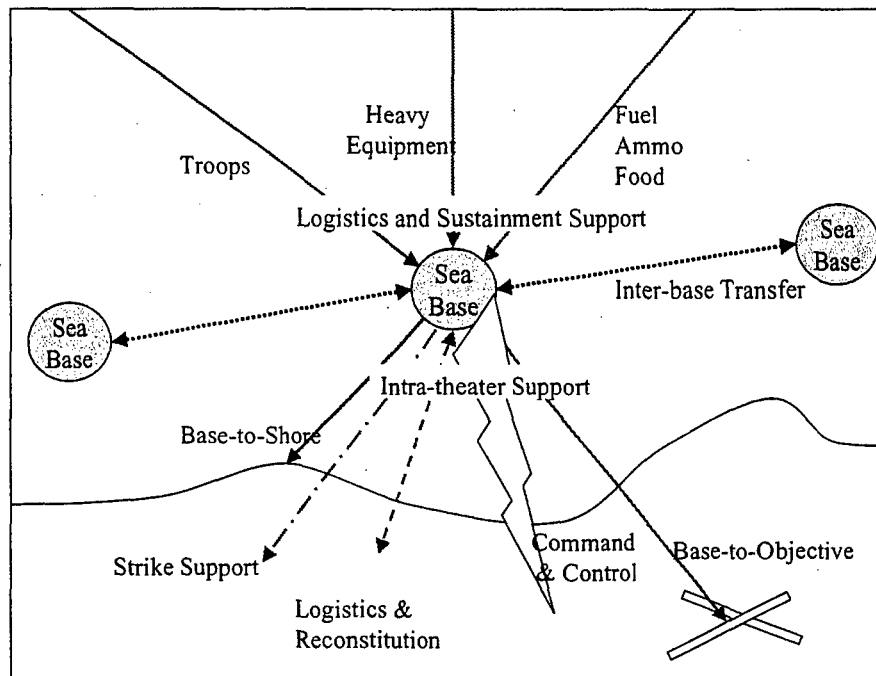


Figure 33 graphically depicts the notional concept behind the CNO's Sea Power 21 SeaBasing concept⁷¹. There are currently innumerable concepts for what constitutes a "SeaBase", but most share a common operating principle of a logistics transfer and distribution center at sea.

Land based distribution centers, whether they are for military or civilian purposes tend to occupy a very large "footprint". They need expansive areas of land for storage, sorting, and breakout of supplies for the end user. It is the elimination of this "footprint" on land, and its

⁷⁰ Clark, Vern, "Sea Power 21, Projecting Decisive Joint Capabilities," Naval Institute Proceedings. OCT 02. [Retrieved from www.chinfo.navy.mil/navpalib/cno/proceedings.html]. 22 FEB 05.

⁷¹ Gold A., Johnson A., West E., Wolf R., "Intermediate Transfer Ship," Design Report. Massachusetts Institute of Technology. 02 APR 05.

associated diplomatic agreements that is one of the main drivers behind the CNO's SeaBasing initiative. Unfortunately moving a logistics distribution center to sea does nothing to diminish the requirements for a large footprint. However, operating a logistics distribution center at sea does place real limits on its size, due to realistic limits on ship sizes. Therefore, in order to produce the same capabilities of a shore-based distribution center in a sea based environment, operations need to be performed using specialized equipment, very efficiently, in a much smaller operating area.

Some of the current proposals have the sea-based distribution centers operating with many of the same principles of their land-based counterparts. In order to enable the high cargo throughput of any forward logistics operation, the sea-based distribution center will need to be able to accept supplies in standard commercial ISO containers. Much like what is done on land, the sea-based distribution center will need to be able to break the commercial containers down into smaller packages that can be more easily handled by forward operating units. Unlike land based centers, a sea-based center will not have the space necessary to break the containers down using the methods of today's military, see [Figure 34](#).

Instead of completely breaking the containers down, as was done in [Figure 34](#)⁷², many proposals for sea-based distribution centers have the platform using smart warehousing technology concepts, such as NAVSTORS, to selectively retrieve only the needed containers from their holds, [Figure 35](#)⁷³. Once retrieved the commercial container would be emptied, using automated technology, of its RFID equipped, standard sized logistics container.

This is where the JMIC concept fits into the SeaBasing CONOPS. By being RFID equipped and standard sized, JMIC enables the smart warehousing technology that is necessary to operate a normally large footprint land-based distribution center in a relatively small sea-based environment.

Once emptied from commercial TEU containers, JMICs could easily, and rapidly be transferred into cargo aircraft, helicopters, or rolling stock (Tanks, Trucks, etc.) set to be moved from the sea-based distribution ship into the battlefield.

⁷² Joint Inter Logistics Working Group Presentation. NSWCICHD PHS&T. 08 DEC 04.

⁷³ Johnson M., Lapointe C., Mosman J., "Intermediate Transfer Ship Conversion Design," Design Report. Massachusetts Institute of Technology. 02 APR 05.

Figure 34: Commercial TEU Containers Stacked at Forward Logistics Area



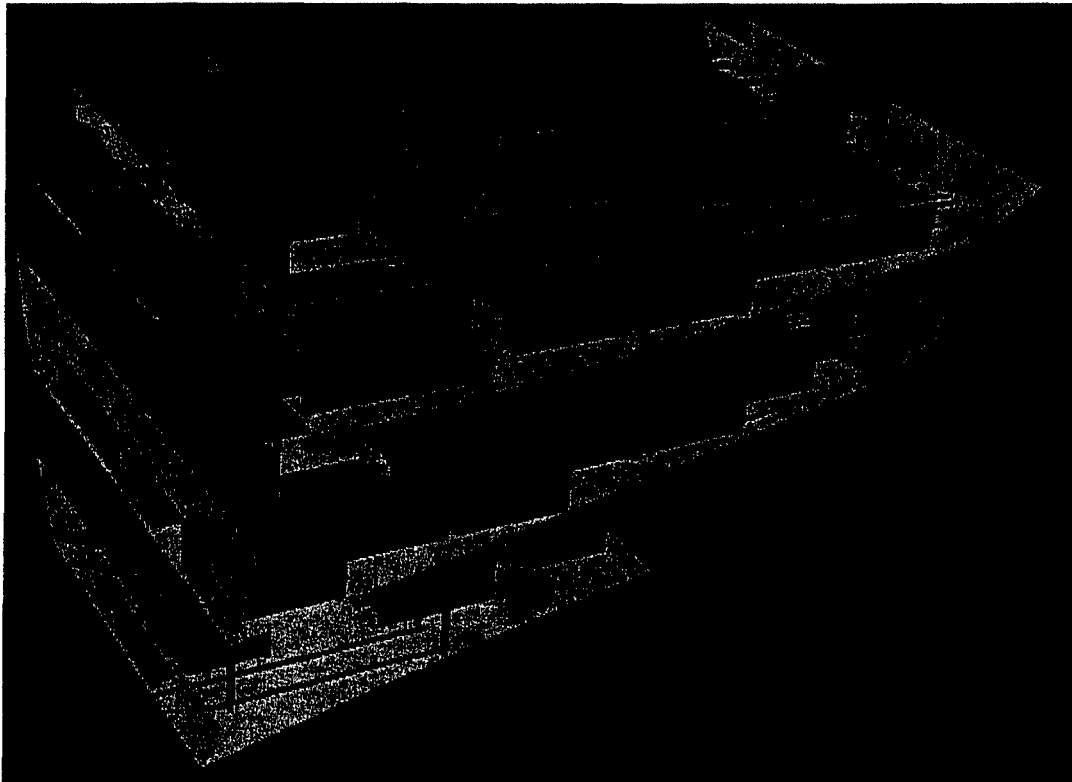
Same Containers Unloaded



Some of the ship designs in the SeaBasing concept already include plans for automated-warehousing systems (see MPF(F), Section 5.b.1). Therefore, incorporating JMIC enabling systems into these designs will not be overly difficult. That is assuming a JMIC, or another standard intermodal container concept, is adopted by the applicable military branches before the SeaBasing ship designs are finalized.

Along those lines United States Transportation Command (USTRANSCOM) recently ordered that all intermodal container concepts currently in development by the different branches of the military start operating under the USTRANSCOM development cycle⁷⁴. The driving force behind this directive was that USTRANSCOM recognized the need for small intermodal containers in future military logistics concepts, and wanted to be sure that the development efforts by each branch of the military were, as much as possible, not being duplicated, and that as much standardization as possible could be incorporated into the differing development pipelines. Currently the first combined branch development meeting is planned for spring of 2005.

Figure 35: Concept for Shipboard Selected Container Retrieval System



⁷⁴ "Joint Intermodal Working Group Restructuring," Email. Mrs. Connie Han. NSWCIIHD-PHS&T. 05 MAR 05.

5. JMIC Compatibility with New Ship Designs

The logistics systems present in the current United States Naval Fleet make the incorporation of JMIC into the ship's logistics cycle very difficult and expensive for anything besides ordnance transfer. As noted before, the JMIC system is being designed to handle a large variety of naval supplies, not just ordnance. The real driving force for developing a JMIC, or other small intermodal container, system now is so future naval ship designs can incorporate the JMIC program into the ship's logistics transfer system.

In some respects small intermodal container system development is almost a cart-before-the-horse development quandary, as is the case with most revolutionary system development cycles. One could argue, at least from a Navy perspective, that it does not make sense to develop an intermodal container concept until a ship is designed and built to fully take advantage of such a system. However, without the intermodal container system to design a ship around, the future ship designers will be forced to pick their own standard intermodal system dimensions and capacities. Using history as a guide these standards probably would not prove to be ideal across the entire military logistics pipeline, or for that matter even within the Navy's logistics architecture. Therefore, it makes economic and developmental sense to design and build the standardized intermodal container concepts prior to building any ships that could fully utilize the system for maximum logistics efficiency. The following sections briefly examine the logistics systems planned for future US Naval ship designs and the possible compatibility of a JMIC like system in those designs. Note: Because of the unclassified nature of this thesis it is not possible to discuss future naval ship designs in any great detail.

a. Combatants

Combatant design is different than almost every other type of commercial ship design in that logistics is not the primary focus of the ship's mission. With the exception of fishing vessels, pleasure craft, and small segments of specialized ship designs, all commercial ships are primarily designed with a particular logistics mission in mind. This primary focus allows the logistics system to be designed in its most efficient configuration and then the rest of the ship to be designed around the logistics system.

In combatant design the primary mission of the ship is to conduct a certain type of warfare and be survivable in a warfare environment. These warfare requirements tend to drive combatant design, and all other missions of the ship are of secondary importance. Because of this focus on power projection and survivability, secondary combatant capabilities such as logistics tend to not exist in the most efficient configuration possible. This design focus makes incorporating revolutionary logistics systems like intermodal containers into combatant design very difficult.

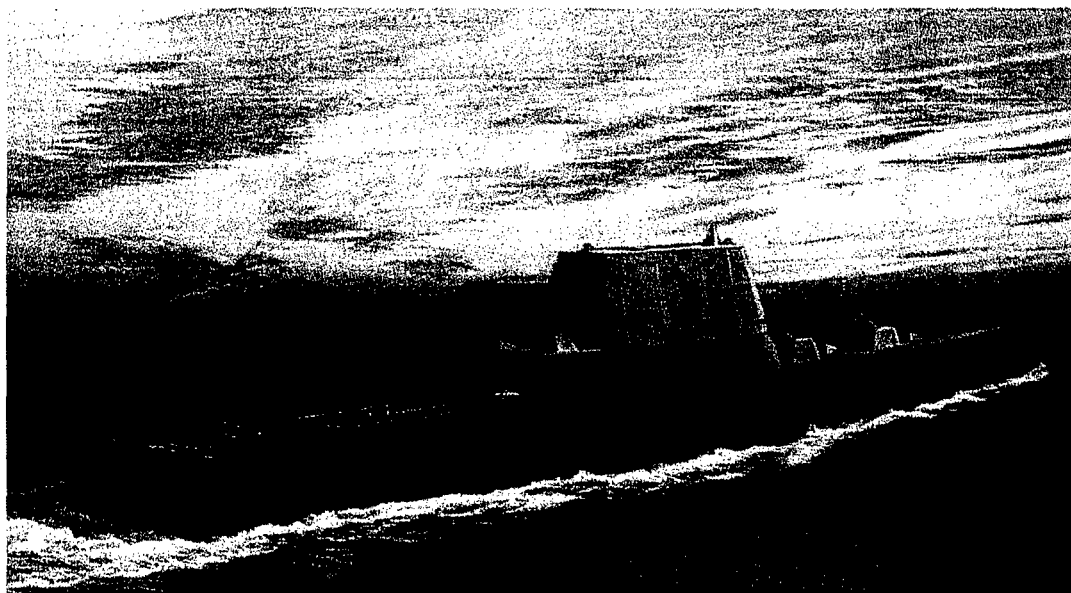
1. DD(X)

The DD(X) is a new destroyer concept, see Figure 36⁷⁵. The combat mission profile for the ship is still in the process of being finalized, but what is known is that the ship will have a long-range gun with land-attack capability, a very small radar cross-section (RCS), and a small crew size when compared to the Navy's current destroyers on the line.

The requirement for a small crew size has forced the ship's designers to incorporate a great deal of automation into every major ship system. The ship's logistics systems are no exception.

⁷⁵ [Retrieved from www.news.navy.mil/management/photodb/photos/030606-N-0000X-002.jpg]. 03 MAR 05.

Figure 36: Artists Conceptual Drawing of DD(X)



The ship's primary weapon is a long-range battery known as the Advanced Gun System (AGS). In order to meet firing rate requirements, and reduce the manning necessary to reload the AGS, the gun designers settled on a "gun clip" type system for weapon reload. As part of the ships UNREP concept, it is re-armed at sea by transferring preloaded "gun-clips" of ammunition from a ordnance CLF ship to the DD(X). Externally the AGS "gun-clips" resemble small standard sized containers. Because the AGS re-arming system was successful in reducing the size of the ship's weapons department, and because the ship already had an external and internal system designed to move these "gun-clips" (or small standardized containers) around the ship, the DD(X) designers began to look at other ways standard sized container concepts could reduce the ship's manning requirements.

One concept the designers chose to adopt is known as Storeroom-in-a-Box, or SIB. SIB is a concept where all the ships food provisions, dry, chill, and freeze, are transported to the ship in standard sized containers preloaded to conform with the United States Navy's 21 day cycle menu. Once aboard the ship the SIB boxes are transferred to the appropriate storerooms using automated systems, where in the case of the freeze and chill boxes they are married up with portable refrigeration units. Using RFID enabled inventory and automation control techniques, individual SIB boxes will be able to be automatically transported to and from the storerooms to the ship's galley, where the cooks will open the boxes to retrieve the necessary provisions.

The SIB boxes share much of the same technology and components as a JMIC system. Currently the two systems have different dimensions and capacities, but development talks are ongoing to determine possible synergies between the two systems. The DD(X) design is fairly far advanced, and because the dimensions of the SIB are bound by the dimensions of the AGS automated transfer system, it is very unlikely that the SIB dimensions will be changed at this point. It is possible that if a JMIC, or other, system of standardized containers is adopted as the Navy or military standard, SIBs could one day be delivered to DD(X) platforms encapsulated in some size of standardized container. Once delivered to the DD(X) the standardized container shell would be removed (retrograded or discarded, depending on cost) and the SIB placed into the ship's automated transfer system.

2. Littoral Combat Ship

The Littoral Combat Ship (LCS) is a small, fast combatant designed to operate in the littoral, or close to the coastline, environment. The US Navy is currently funding the development of two prototypes, Figure 37⁷⁶. Both ships have similar logistics requirements because of their small crew sizes and modular mission payload design. In order to facilitate rapid in-port modular mission change out, both designs currently incorporate some storage areas for 20 ft ISO containers.

The 20 ft containers stored on-board are only designed to be changed out in-port. However, because JMIC fits within the 20 ft ISO footprint, there exists the possibility that in the future JMICs could be transferred to the LCS at sea and then stored in the ISO storage area.

⁷⁶ [Retrieved From www.peoships.crane.navy.mil/lcs/default.htm]. 03 MAR 05.

Because of the ongoing design competition it is currently difficult to obtain information on the two competing LCS designs, with most information falling under each consortium's proprietary umbrella. This lack of detailed information makes it difficult to accurately gauge JMICs complete applicability to the LCS platform, but the information that is known seems encouraging.

The ships' small size makes automated warehousing concepts impractical, but their rapid mission reconfiguration CONOPS is a good argument for standardized container concepts. The bottom line is that LCS should be able to have limited effective use of JMIC or another intermodal container concept should it become widely adopted in the military logistics system.

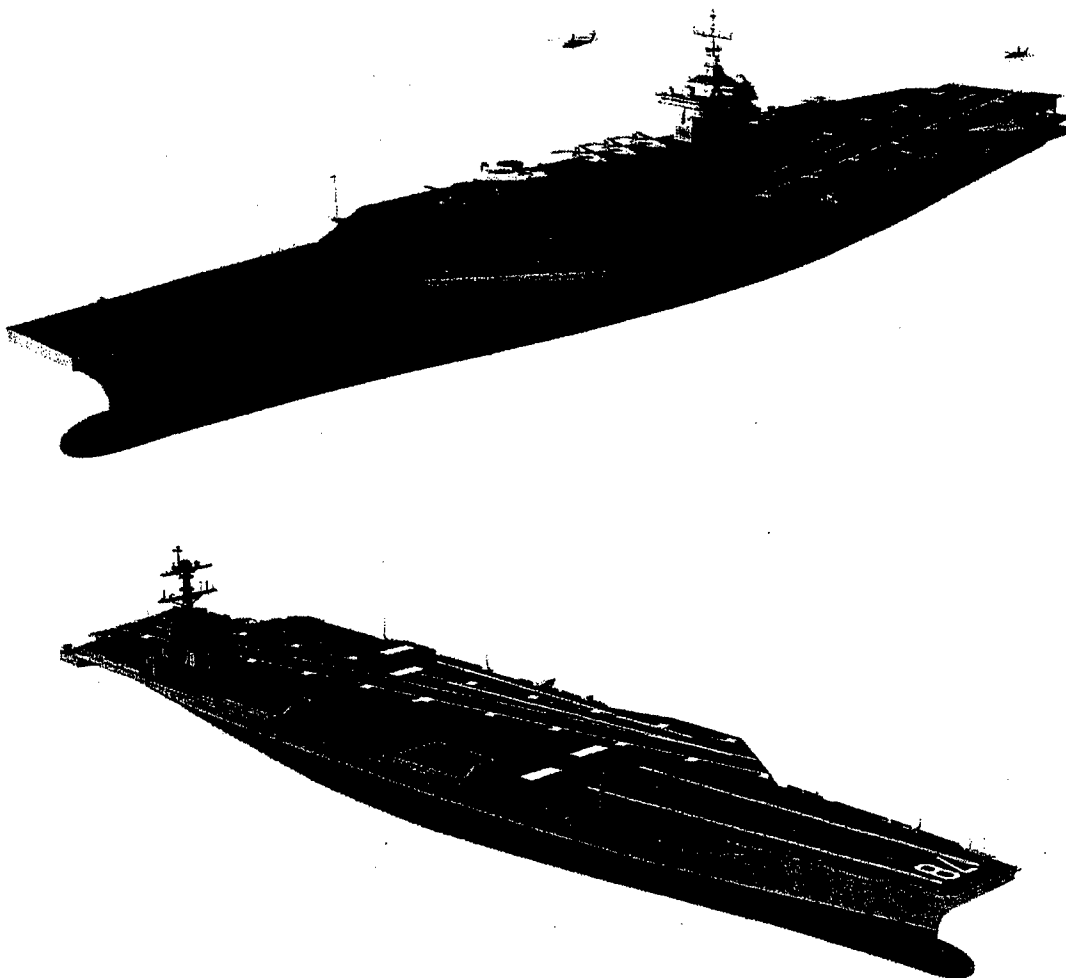
Figure 37: Two Competing LCS Prototype Designs



3. CVN-77/CVN-21

CVN-77 ([Figure 38⁷⁷](#)) is the bridge design between CVN-68 Nimitz Class Aircraft Carriers and CVN-21 ([Figure 38⁷⁸](#)), the United States Navy's aircraft carrier design for the 21st century. As a bridge design CVN-77 retains many of the characteristics of the CVN-68 class, but is also being used as a test platform for many of the concepts being designed for implementation on the CVN-21 class ships.

Figure 38: Artist's Concepts of CVN-77/CVN-21



⁷⁷[Retrieved from www.navsource.org/archives/02/77.htm]. 03 MAR 05.

⁷⁸[Retrieved from www.nn.northropgrumman.com/news/2004/040216_dcs03-41.jpg]. 03 MAR 05.

In addition to an upgrade of many of the aircraft carriers' major systems to 21st century technology a major focus of the CVN-77/CVN-21 design is a reduction in the total ownership cost (TOC) of operating these immense ships⁷⁹. A large portion of the CVN-68 Nimitz Class Aircraft Carriers TOC is manning. Nimitz class ships deploy to sea with crews in excess of 5,000 sailors when fully operational.

The CVN-77/CVN-21 designs aim to have increased operational capability over CVN-68, albeit with a reduced manning structure. Every major ship system of the new design has been put under intense review to determine where manning requirements could be reduced through the use of automation, without sacrificing system functionality. The ship's logistics systems were no exception. Studies are currently ongoing to reduce manning in the ship's supply departments through galley redesigns, stores transfer methods, and heavy UNREP capability. Weapons department downsizing is being enabled through the use of automated magazine storage systems such as NAVSTORS. The ship's Reactor department manning is being reduced, while electrical power available levels are increased, through a complete reactor plant redesign⁸⁰. Various changes such as these could be described for every department on the ship, and are the result of years of research focused on updating a 1960's era aircraft carrier design for the 21st century.

a. CVN-77

The most interesting aspects of the CVN-77 redesign from a JMIC perspective deal with the ship's stores and weapons transfer methods. The NAVSTORS system being considered for the ship's weapons magazines, and its applicability to a JMIC logistics system, has already been described in this paper (Section B.4). The more revolutionary aspect of the CVN-77 design, at least from a JMIC system complete accessibility perspective, is the proposal to eliminate package conveyors from the ship and instead replace them with stores elevators⁸¹.

⁷⁹ CVN-21. [Retrieved From <http://www.globalsecurity.org/military/systems/ship/cvx.htm>]. 06 MAR 05.

⁸⁰ Ibid.

⁸¹ Conversation with Mr. John Cavalieri, NSWCCD-SSES. 28 FEB 05.

By replacing the package conveyors with stores elevators the CVN-77 design eliminates the major design deficiency present in all other non-CLF classes of naval ship, when considering the total compatibility of a JMIC system. The stores elevator system was not designed around JMIC's parameters, but instead was designed with the recognition that package conveyors do not serve the ships requirements when increased sortie requirements are considered.

Increased sortie requirements meant that CVN-77 could no longer afford to have the ship's hangar bay clogged with half-broken down pallets, many hours after the connected portion of the UNREP was complete. Instead the ships needed to have the capability to quickly move pallets of stores from aircraft operational areas to storerooms below, where they could then be broken down and stored with less impact on the ship's operational tempo. By incorporating stores elevators into the CVN-77 design the ship's designers incorporated a system that was a good fit for a JMIC type standardized container. In fact as the designers continue to refine their initial designs, and look for areas to increase automation and further reduce manning requirements, they have begun to examine standardized intermodal container concepts for use in CVN-77⁸². One aspect of the design that needs to undergo further revision to incorporate standardized containers is the storerooms themselves. Currently the system is designed such that pallets can be brought down on the stores elevators to a breakdown area, where they are broken down and passed into the ships' storerooms⁸³. To truly take advantage of a standardized container concept the ships' storerooms would need to be redesigned such that pallet size loads could be passed directly into the storerooms. Not only would this enable the improved storage aspects of a JMIC system vs. wooden pallets, but would also make it possible to implement automated storage and retrieval systems as they became available for shipboard use.

⁸² Ibid.

⁸³ Conversation with Mr. John Cavalieri, NSWCCD-SSSES. 28 FEB 2005

b. CVN-21

CVN-21 is the first completely new United States Navy Aircraft Carrier design in almost four decades. Because the ship is being designed from a 'clean sheet of paper' the ship's designers could make many changes that were simply not feasible, structurally or economically, on a transitional design like CVN-77. One of the many areas of the ship that CVN-21's designers chose to make significant changes from past aircraft carrier designs was in the ships logistics systems.

CVN-21's designers have made a concerted effort to consolidate the ships storerooms in accessible areas, as opposed to being scattered throughout the ship, as is the case with most current US Naval ship designs. The larger, consolidated storerooms have been designed with large doorways and strengthened decks to accommodate supplies in pallet size configurations. In addition, elevators capable of transporting palletized supplies service the larger ship's storerooms⁸⁴.

These design changes will make CVN-21 the first naval combatant truly suited to use intermodal container systems, like JMIC, in their most efficient manner. The ship's designers, driven by supply throughput requirements, decreased crew size, and a general emphasis on logistics ergonomic flow have recognized the break-bulk supply handling methods of the US Navy's past will not continue to be a viable option for its large combatants of the future. The question whether CVN-21's future supplies will continue to arrive in shrink-wrapped wooden pallets, or in intermodal containers, has yet to be answered, but at least the ship is being designed to handle both possibilities.

⁸⁴ "CVN78 Material Movement Findings/Conclusions," Northrup Grumman Corporation. 20 APR 05.

b. Auxiliary Ships

Auxiliary ships differ from combatants in that, much like most commercial ship designs, auxiliary ships tend to be designed around a logistics mission. This focus on the logistics mission of the ship allows the auxiliary ship designer to develop the ship's logistics systems in the most efficient configuration possible, and then build the rest of the ship around the logistics system design. Because of this design concept most new auxiliary ship designs tend to include some innovations in logistics system design and are well suited to take advantage of small intermodal container systems like JMIC.

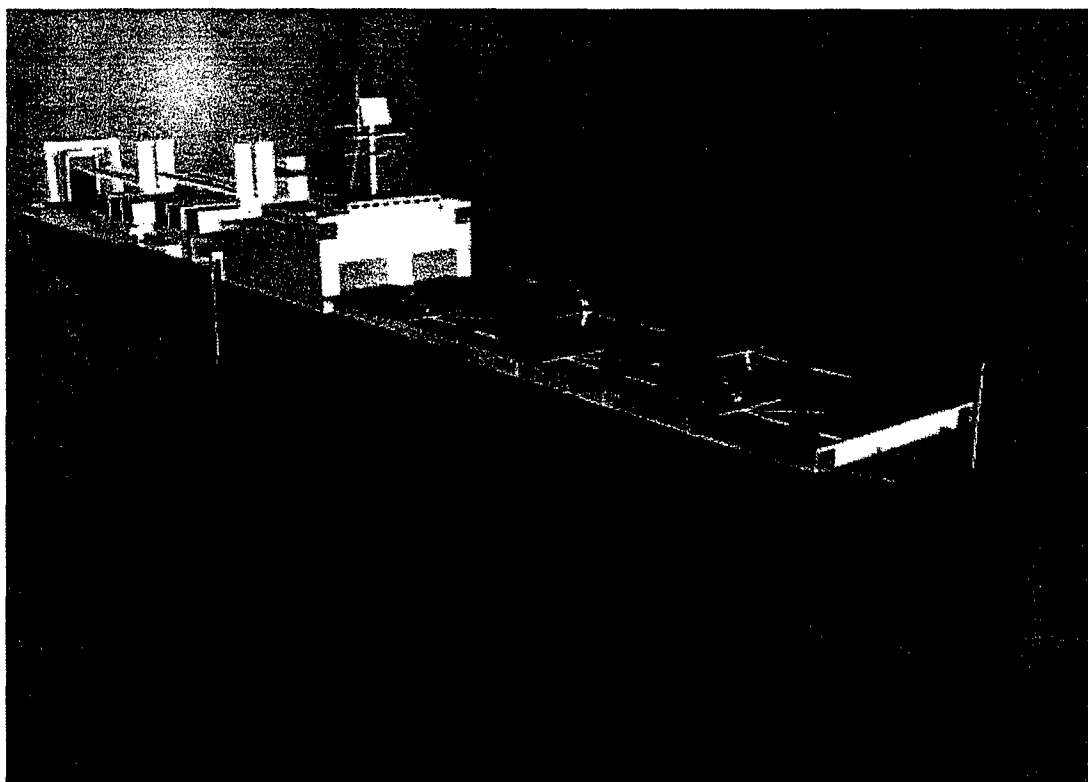
1. MPF(F)

MPF(F), or Maritime Prepositioning Force (Future), is a concept for a class of auxiliary ships designed to replace the current Maritime Prepositioning Force ships in use today. The prepositioning force exists as a means of storing bulky Marine Corps and Army material in forward operating areas, so that the material can be rapidly joined up with incoming troops in times of crises. The current MPF ships are a mix of break-bulk carriers, containerships, and Ro-Ro's. Most do not significantly differ from their equivalent commercial ship design. The ships are designed to offload their material into a port being held by friendly forces.

Concept designs for MPF(F) ships tend to have more of a SeaBasing focus. Unlike current MPF ships they generally have methods of offloading their material other than in a friendly held port. Some concepts incorporate flight decks, well decks, LCAC "lilly pads", etc., Figure 39⁸⁵.

⁸⁵ [Retrieved From [www.peoships.crane.navy.mil/pms325/futureships/MPF\(F\)/MPF1.jpg](http://www.peoships.crane.navy.mil/pms325/futureships/MPF(F)/MPF1.jpg)]. 29 MAR 05.

Figure 39: Artist Concept of a MPF(F) Ship



Because the MPF(F) ships are being designed with the logistics mission as the ships' primary mission focus, they generally include the latest shipboard technology for logistics material transfer. Many of the ships in the MPF(F) squadron are being designed to handle supplies in 20 ft ISO containers, as well as incorporating smart warehousing systems for selective stowage and retrieval of material. 20 ft ISO containers, and small intermodal container systems such as JMIC, are poised to serve as the backbone of the SeaBased logistics transfer system using the ships proposed for the MPF(F) squadron.

20 ft ISO containers used in conjunction with HiCASS (High Capacity Alongside Sustainment) will allow high capacity transfer of large amounts of material to the MPF(F) ships, while JMIC or other intermodal systems, will allow the 20 ft containers to be broken down into smaller standardized packages for transfer to waiting aircraft or LCAC's. Small intermodal packaging within the 20 ft ISO footprint will also allow for easier selective stowage and retrieval of material within the ISO containers, a key enabling concept of the working SeaBase design.

JMIC, or another intermodal packaging system, is a key element of the working SeaBase logistics transfer system and will need to be developed and implemented for the United States Navy's SeaBasing concept to work as proposed.

2. T-AKE/T-AOE(X)

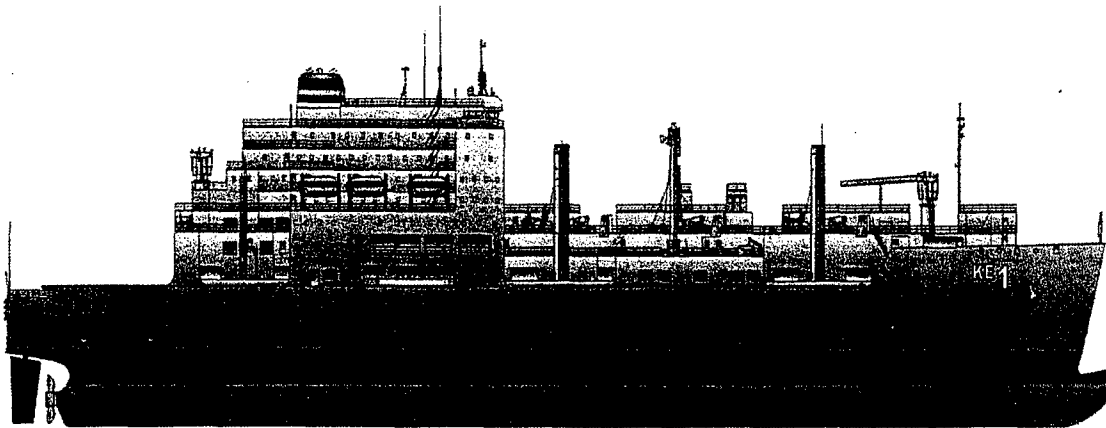
T-AKE and T-AOE(X) are the United States Navy's answer for updating its Combat Logistics Force (CLF) fleet for 21st century operations. With both ships being designed with a logistics based focus they are both relatively compatible with a JMIC type intermodal container system.

T-AKE, an auxiliary cargo and ammunition ship, is being designed as a replacement to the T-AE and T-AFS class ships currently in the United States Navy inventory. The design phase is complete and ships are already under construction. The first ship in the class, USNS LEWIS AND CLARK (Figure 40) is due to be delivered in 2007⁸⁶. The T-AKE, like other CLF ships, is designed to handle supplies and ordnance in pallet sized loads, making it suitable for JMIC. The T-AKE also contains upgraded information technology systems when compared to other CLF ships currently in the Navy inventory; this will give the ship an advantage when handling the RFID portion of the intermodal container system package⁸⁷. What the T-AKE does not have is a fully automated shipboard warehousing system, and the ship in its current configuration would not be able use a JMIC like intermodal container system in its most efficient mode.

⁸⁶ [Retrieved From www.msc.navy.mil/factsheet/t-ake.htm]. 29 MAR 05.

⁸⁷ "T-AKE Operational Requirements Document," [Retrieved from www.globalsecurity.org/military/systems/ship/take-ref.htm]. 29 MAR 05.

Figure 40: USNS LEWIS AND CLARK, First Ship in new T-AKE Class



T-AOE(X) is the US Navy's concept for the next generation of the triple product support ship, to replace the recently decommissioned AOE-1 class and augment the AOE-6 class ships built in the 1990's. The ship is currently in the early concept phase and is scheduled to begin the acquisition process in 2009⁸⁸.

Figure 41, shows an early artist's concept of what the ship might look like⁸⁹. Because the ship design is so early in the development cycle, and because the ship is being designed around a logistics mission, T-AOE(X) has the possibility of being the first CLF ship designed to use small intermodal container systems in the most efficient manner. That is assuming that intermodal container system development has sufficiently progressed to the point where it can be included in the T-AOE(X) design, once the design begins to take its final development form.

⁸⁸ "Winning Today While Transforming to Win Tomorrow," Remarks of Secretary of the Navy to Congress. 17 FEB 05. [Retrieved From www.chinfo.navy.mil/navpalib/people/secnav/england/testimony/england050217.tx]. 20 MAR 05.

⁸⁹ [Retrieved From www.globalsecurity.org/military/systems/ship/taoe-schem.htm]. 29 MAR 05.

Figure 41: Artist Concept of T-AOE(X)



D. Commercial Alternatives to JMIC

The main purpose of this thesis is to examine the Concept-of-Operations for best utilizing the JMIC container system within the military logistics pipeline. However, the thesis would not be complete without at least mentioning that there are alternative small intermodal container systems, besides JMIC, currently available. Some of these container systems are still in the development stage, like JMIC, while others have already been produced and are being used in commercial and military logistics applications.

Other researchers, in both the Navy and other branches of the military, are currently studying the wide range of commercial container systems available for their military application. This thesis simply aims to point out some of the different classes of commercial systems available, and compare some of their similarities and differences to the proposed JMIC system.

a. Rigid Box Containers

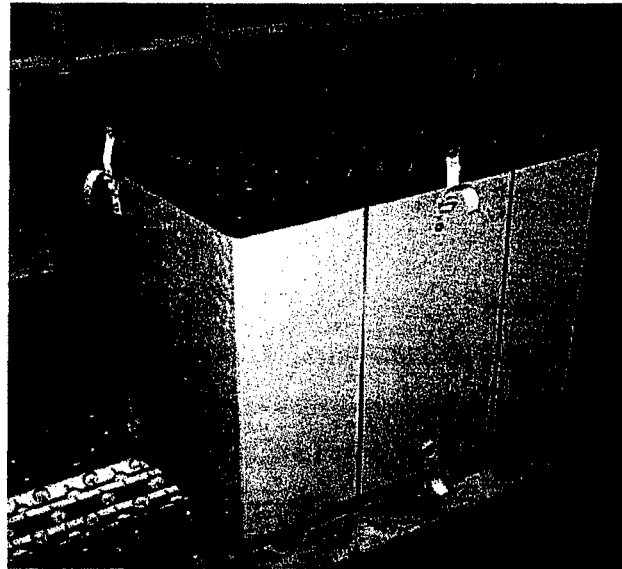
Rigid box containers are in general nothing more than stronger versions of the ubiquitous corrugated cardboard box. Figure 42, shows an example of a typical commercially available rigid box container⁹⁰. Containers of this type are relatively cheap, light, and have low strength characteristics. Most containers in this class are made out of some type of plastic, such as polyethylene, or even reinforced corrugated cardboard.

Rigid box container systems do have some nice features. They are in general very low cost (in some cases the cost is low enough for the containers themselves to be considered disposable), lightweight (especially important when considering airlift operations), and do a good job as serving as a consolidation container for other smaller packages (especially when the smaller packages themselves are lightweight). Some of the container systems have the ability to be stacked, depending on the weight of their contents, and also contain fork pockets for manipulation by fork trucks.

⁹⁰ "Joint Modular Intermodal Container," Business Case Report. NSWCIHD, Detachment Earle, Packaging, Handling, Storage, and Transportation Center. 20 FEB 05.

The main disadvantage of these types of containers is that they are low strength. Their low strength limits their stacking ability when loaded with heavy cargo, and in general necessitates a lot of external banding and bracing (much like shrink-wrapped wooden pallets) when used in material transfer applications, especially on aircraft. Rigid box containers are in limited military use, primarily in airlift operations on top of Air Force 463L pallets.

Figure 42: Typical Example of a Rigid Box Container

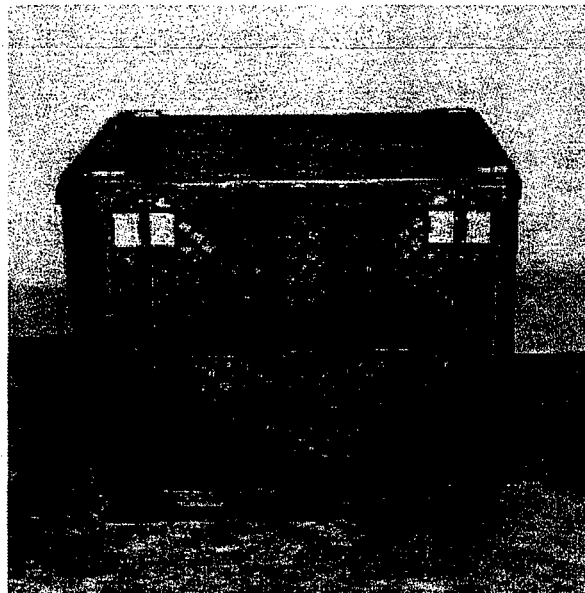


b. Molded Plastic Containers

Most molded plastic containers resemble oversize milk crates, [Figure 43](#)⁹¹. They are in general stronger, heavier, and more costly than rigid box containers. Some come with fork pockets but most are designed to sit on top of another type of pallet. The strength of these containers is such that they can normally be stacked, again depending on the weight of their cargo. These containers fill the middle ground on weight, cost, and strength between relatively flimsy rigid box containers, and strong steel or other metal containers.

⁹¹ Ibid

Figure 43: Molded Plastic Containers



c. Metal Mesh/Metal Sidepanel Containers

There are a variety of metal mesh and metal side panel intermodal containers available commercially. Some have been designed and built to fill very specific applications, while others have been designed as relatively strong, general purpose, carryall containers.

In general the metal mesh containers fill the same niche as molded plastic containers, albeit with greater strength and weight. Because of material cost they also tend to be more expensive than their molded plastic brethren.

Figure 44, shows examples of typical metal mesh and metal side panel containers^{92,93}. At first glance most metal side panel containers have much the same outward appearance as the JMIC prototype. However, because these commercially available containers were not built to military specifications they typically do not pass the strength testing necessary to allow them to carry ordnance⁹⁴.

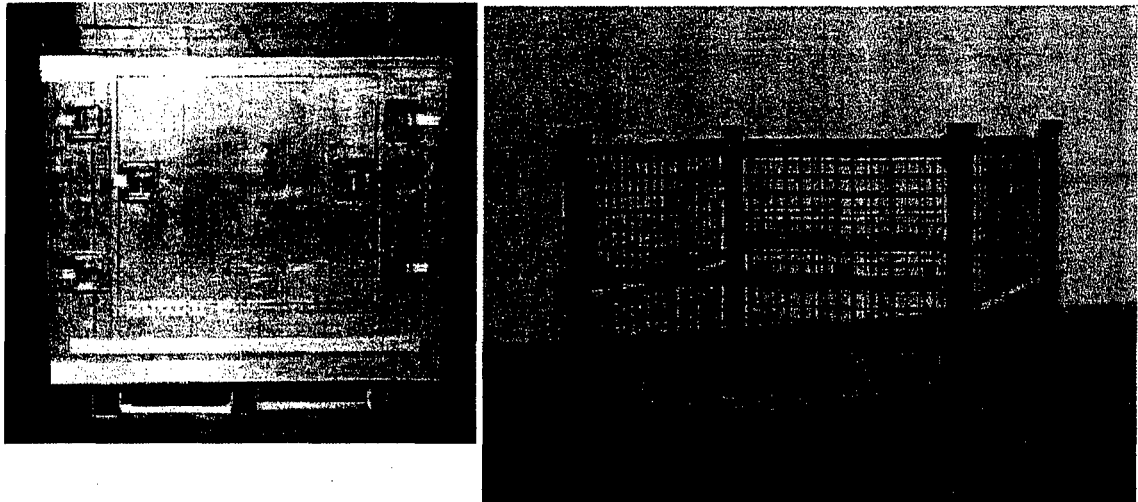
⁹² Ibid

⁹³ "Army Joint Modular Intermodal Container Program," Armament Research Engineering Development Center, Logistics Research and Engineering Directorate, Picatinny, New Jersey. 08 DEC 04.

⁹⁴ "Joint Modular Intermodal Container," Business Case Report. NSWCICHD, Detachment Earle, Packaging, Handling, Storage, and Transportation Center. 20 FEB 05.

When compared to rigid box, and molded plastic designs, metal mesh and metal side panel boxes are in general heavier, stronger, and more costly, as would be expected. However, there exists a wide variance within this class of containers, primarily due to the strength, weight, and cost differences between aluminum, steel, and stainless steel.

Figure 44: Typical Metal Mesh/Metal Side panel Containers



E. The Road Ahead for JMIC Development

The Joint Modular Intermodal Container system (JMIC) is still in the infancy of its development. Conceived from a logistics working group idea and recognition that small standardized containers were going to revolutionize military logistics, JMIC is perhaps one answer to the problems associated updating the military logistics system with 21st century technology advancements.

Because it is in such an early stage of its development cycle, the JMIC system is in a constant state of update and overhaul. Based on customer feedback and their own capability design reviews, NSWCIHDPHS&T has already begun to plan and develop Phase II of their JMIC design, Figure 45⁹⁵.

With the recognition that the JMIC containers will not only vary in size and material of construction, Phase II of the JMIC design attempts to introduce more variability in the JMIC containers configuration. The Phase II design allows the user to more easily configure the type of siding to use on the container. For example a wire mesh, or lightweight plastic sheet might be used with JMIC to carry lower value commodities such as toiletries or soda, while rigid aluminum panels could be used to protect high value items from damage. The Phase II design also allows the customer to use just the JMIC base, in place of a steel pallet, or the base and the side posts (perhaps with additional strapping), to carry a wide variety of loads. By incorporating these changes into the Phase II JMIC the designers aim to introduce a broader range of available JMIC containers, both in terms of cost and weight, hoping to appeal to a wider range of military logisticians.

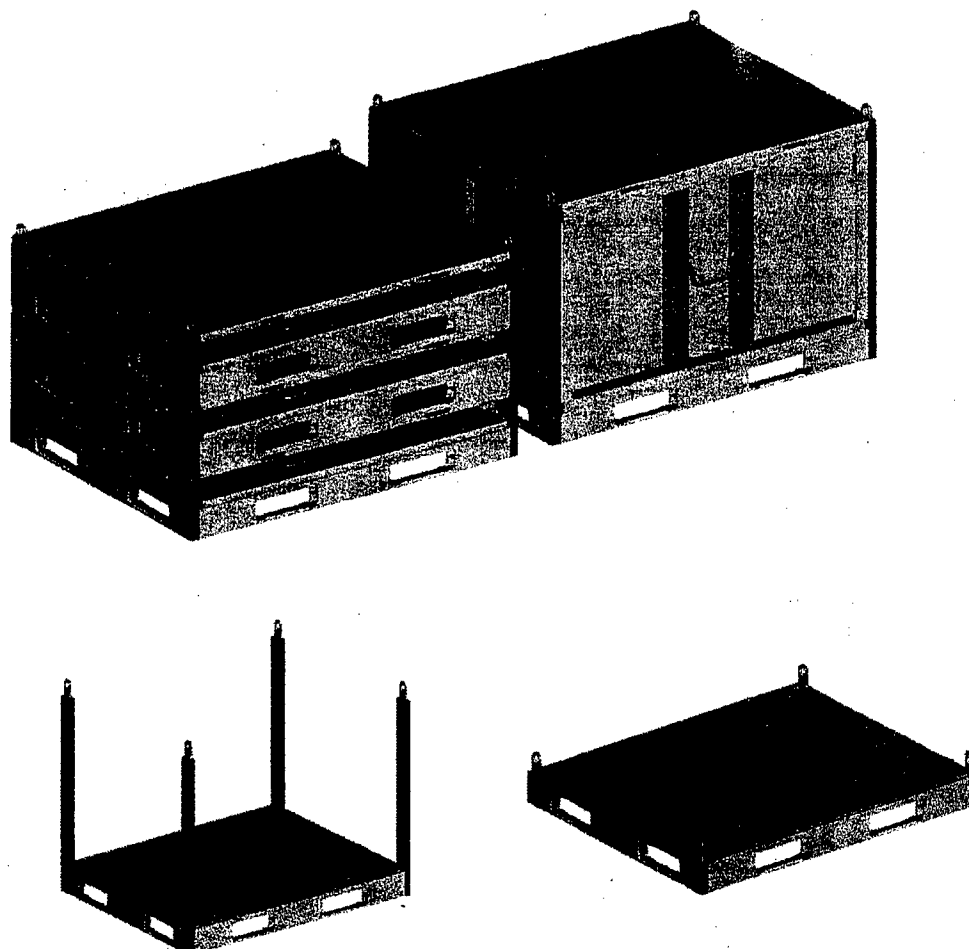
Perhaps the biggest addition to the Phase II design, and one of the main criticisms of the Phase I design, is the introduction of top-lift capability. Top-lift capability makes it much easier to incorporate JMIC into an automated handling system, as most automated systems use top-lifting designs due to decreased complexity of the necessary robotics.

Figure 46 shows how JMIC's Phase II top-lifting capability could be utilized to rapidly transfer several JMICs at one time, perhaps greatly decreasing the time needed to load pierside logistics vessels⁹⁶.

⁹⁵ "JMIC Phase II Design Objectives," Draft presentation given by NSWCIHDPHS&T. 15 MAR 05.

⁹⁶ Ibid.

Figure 45: Proposed Phase II JMIC Configurations

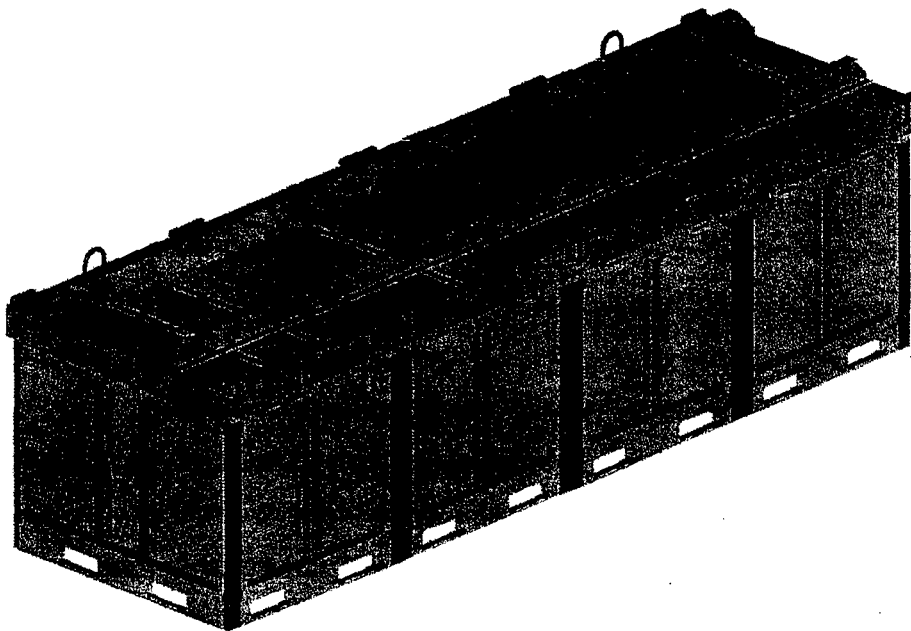


JMIC Phase II design also addresses customer concerns with the Phase I design concerning the incompatibility of Phase I with pallet trucks. The Phase II JMIC base has been redesigned to allow the container to be carried by both fork trucks and pallet trucks.

The development road ahead for JMIC is long and twisted. The newest prototype iteration by no means maximizes JMIC's usefulness for all potential customers, although it does address some of the major shortfalls of the previous prototype. Further prototype design iterations are sure to follow, as customer feedback and internal design reviews are applied to the current Phase II prototype.

At some point the plan is for the JMIC prototype to complete its initial design phase, and for the design to be passed over to commercial industry for further redesign and perhaps initial small-scale production. Once JMIC reaches that development milestone more widespread fleet and production testing are bound to have large effects on the systems design, and test data taken during this phase will go a long way in determining if JMIC will be a viable program for fleet-wide, and perhaps military wide introduction.

Figure 46: Multiple JMIC Transfer by Utilizing Top-Lift Capability



III. PROS AND CONS OF JMIC WITHIN NAVAL LOGISTICS ARCHITECTURE

A. JUSTIFICATION FOR STANDARDIZED SHIPPING

As the United States Military begins to examine how to best incorporate small intermodal containers into its logistics architecture, it is facing many of the same technical and economic issues that were encountered by the commercial break-bulk shipping industry as it began to switch to containerized shipping in the 1960's.

1. Commercial Containerization in the 1960's

In the late 1950's, Malcolm McLean, a trucking company owner (and eventual shipping company pioneer), had an idea that it would be much more efficient to lift the entire box off the back of his trucks and place it on a waiting ship, instead of the current process of unloading goods from his truck boxes and re-stowing them in ship's holds⁹⁷. McLean used this idea to start a revolution in the commercial shipping industry; for it is from this idea that the current commercial containerized shipping industry was born.

It is obvious today that containerization has revolutionized the break-bulk shipping industry, but in the late 1950's early 1960's this was not a forgone conclusion. There were many issues shippers faced as they began to consider operating containerized ships.

Although it was apparent from the beginning that trucks and ships could be loaded and unloaded faster using containerization, it was not immediately obvious that this would be economically beneficial. For one thing, there was an entire fleet of legacy cargo ships that were not configured to efficiently use containerization, not to mention the lack of container handling equipment in all the world's ports. Furthermore, for the system to be economically efficient containers would have to be standard sized, and all use the same handling gear. Containers were in use for over a decade before the International Standards Organization (ISO) came out with its standardization codes for shipping containers in 1967⁹⁸.

⁹⁷ "Containerized Shipping, Thinking Inside the Box," [Retrieved from www.alteich.com/tidbits/t060401.htm]. 17 MAR 05.

⁹⁸ "Setting Standards, a Phenomenal Success Story," [Retrieved from www.iso.org/iso/en/aboutiso/introduction/fiftv/pdf/settingen.pdf]. 17 MAY 05.

Once containers became standardized the containerized shipping industry really began to emerge as an economic giant. Today if a company wants to ship break-bulk goods across the sea they have very little choice or incentive to ship them in anything other than a shipping container. In fact many would argue that containerized shipping has enabled the ever-increasing globalization of trade the world is witnessing today⁹⁹.

Many parallels can be drawn between the beginnings of containerized ocean shipping and the emergence of small intermodal containers for military logistics. For one it is apparent to all that small intermodal containers should be able to move faster, more efficiently, and with less handling requirements, through the logistics system than the shrink-wrapped wooden pallet in use today. Also, much like the beginnings of the commercial container industry, the military is going to have to deal with a large number of legacy logistics systems and equipment that will not be able to utilize the new intermodal container systems effectively. And it is doubtful that a truly efficient intermodal container system will emerge until the military hierarchy can decide on a standard set of sizes, and more importantly standard interfaces.

Also, like the commercial shipping industry of the late 1950's, the military, and more specifically the US Navy, has a system of procedures in place to work with break-bulk handling of supplies. Some of these procedures will not allow for the efficient processing of unit sized load containers such as JMIC, for example the current practice of using T-AOE's as "one stop shops", where pallets of supplies are assembled and shrink wrapped within the ship's hold for delivery. It has to therefore be considered, besides compatibility issues there will also be large procedural issues that will have to be overcome if the introduction of a small intermodal container system into the military logistics architecture is to work.

Using the history of commercial containerized shipping as a guide it is apparent that a small intermodal container system should be a successful addition to the United States Military logistics architecture. The questions that remain are; will it take over a decade in operation, like commercial containers, for this system to truly begin to make an impact? And, given the legacy issues in the logistics architecture will the system really reduce logistics system total ownership costs?

⁹⁹ Ibid.

2. Decrease in Logistics System Total Ownership Costs (TOC)

No matter what small intermodal container system the military decides to implement (JMIC or an equivalent), the costs of the containers themselves are going to far exceed the costs of the wooden and metal pallets so prevalently used today. What has yet to be determined is if operating a small intermodal container system within the military logistics architecture will indeed lower the overall cost of conducting military logistics.

As stated before, one of the main ways an intermodal container system can lower the cost of military logistics is to cut down on the amount of supplies that are reordered because they are either lost or delayed in the logistics architecture. In addition the decreased material handling requirements, primarily due to automated account and receipt technology inherent with RFID equipped containers, is predicted to have a large effect on overall logistics system cost. Cost savings are predicted to occur both because the system will be able to operate more rapidly, and because fewer personnel will be needed for inventory accounting. Finally, a small intermodal container system is predicted to lower overall logistics system cost by the fact that it should lower the overall size of the logistic system altogether by increasing the system efficiency. The 21st century United States Military is positioning itself as a grouping of relatively small, rapid reaction forces. In order to support a system such as this the military needs an agile, efficient logistics system that can deliver supplies as quickly as rapidly deployed forces need them, as evidenced by the recent events at United States Transportation Command, intermodal container systems are being given a hard look as part of the solution to this dilemma.

B. MAJOR PROBLEMS WITH INTRODUCING JMIC INTO THE NAVAL LOGISTICS INFRASTRUCTURE

The theory behind JMIC and other intermodal container concepts is solid. If such a system is widely adopted system-wide efficiencies can be gained, and overall logistics system ownership costs should be lowered. However, each branch of the military has some tall hurdles to overcome in the implementation of a small intermodal container system. This thesis was mainly focused on those challenges faced by the United States Navy.

1. Incompatibility with Current Platforms

As stated previously the main problem associated with the efficient deployment of JMIC within the Naval logistics architecture is JMIC's incompatibility with current Naval platforms. JMIC is being proposed as a carry-all container, and indeed to achieve system-wide efficiency it needs to be. From an ordnance carrying perspective JMIC, and its family of variants, fit fairly well into the current Naval fleet architecture, as almost all ships have been designed to carry and handle ordnance in pallet size loads.

JMIC's main problem occurs when it is proposed to carry general cargo loads on current Naval platforms. All current Naval ships, with the noted exception of Combat Logistics Force vessels, were not designed to handle general cargo loads in palletized form. What this means for JMIC is that current naval ships have neither the handling equipment (elevators, top-lift cranes, etc.), nor the storerooms to facilitate the use of JMIC in its most efficient form.

Indeed the barriers are such that it is very unlikely that JMIC would ever be used to carry general cargo onboard certain Naval ship classes, the question that remains to be answered is if from an entire United States Navy perspective it makes economic sense to implement a JMIC like logistics system for future platforms when various legacy ship classes will not be able to utilize it?

2. Implementation of JMIC into Future Platforms, a Changing Focus of Warship Design

This thesis has already specified some of the issues facing the implementation of JMIC into future ship designs such as DD(X), LCS, and CVN-21. The bottom lines on all these ships is while they may have some features that make them more JMIC friendly, all the designs are fairly mature, and were started before an intermodal container system such as JMIC was considered. Therefore, none of these future platforms is ideally situated to take advantage of all the benefits a JMIC logistics system has to offer, of the three ship classes CVN-21 is by far the most JMIC compatible.

The future of standardized container logistics systems on warships is inseparably linked to the philosophy behind warship design. Warships in the past have been designed around the ship's battle mission, and future warships will be no different. What perhaps may change will be the importance placed on a warship performing its own logistics functions. While past warship designs may have included extensive ergonomic studies relating to the layout of the combat systems suite, very little attention was given to the logistics spaces on the ship. As a result of this, naval architects tended to arrange the ships logistics spaces last, fitting them in wherever they had room. This design philosophy led to small, odd shaped storerooms placed throughout the ship, storerooms that were completely insufficient to meet the demands of automated warehousing technology and thus JMIC like intermodal container systems.

The question now is with the emphasis on shrinking crew sizes, and the advent of smart warehousing technologies, will the logistics mission of a warship rise on the naval architect's pecking order when designing the ship? Warships will always be a unique type of ship design, and the battle mission and survivability characteristics of the ship will continue to drive the ship's design parameters. But will the potential benefits of streamlined, automated logistics functions be sufficient, such that in future warships designers start to allocate some of the valuable mid-hull real estate to storerooms suitable for automated warehousing technology?

To the non-naval architect the answer to the above question might be an easy yes, but the naval architect knows that warship design is a unique animal. With the exception of a submarine there is no other ship that has system density of a modern naval combatant. The naval architect understands that naval combatants have no "wasted space", and the adding of additional systems, especially ones as space hungry as automated warehousing, will mean tradeoffs. Tradeoffs such that existing ship systems will have to be removed from the ship (not likely to happen with today's streamlined, technology driven warship designs), or that the ships will have to get bigger to accommodate the automated warehousing systems.

What most non-naval architects do not understand about making a warship design larger to accommodate an automated warehousing/intermodal container system is that it is not simply a question of adding enough hull volume to accommodate the new logistics system. Warships are by their nature finely tuned designs, any addition to hull volume to accommodate a new logistics system is likely to throw off another parameter of the ship design, whether it be increased resistance of the larger hull through the water such that the ship no longer meets its speed

requirements, or a change in the hull's stability characteristics due to the added volume. What is likely to occur is that the additional hull volume necessary to accommodate an automated warehousing/intermodal container system on a future warship design is going to force the warship designer to redesign the entire ship envelope, taking the ship through another trip through the "design spiral". The warship that comes out the end of this design is likely to be larger, have more powerful engines, and be much more expensive to build than the design that did not include the space necessary for automated warehousing/intermodal container logistics.

To better illustrate the effects of incorporating an automated warehousing space into a warship design a computer model of a DDG-51 Arleigh Burke class ship was modified to include a storeroom and elevator capable of being used with automated warehousing technology. Two-thirds of the ship's normally dispersed storeroom capacity was combined into one 10 X 17 meter central storeroom, located directly over Auxiliary Machinery Room #2. Along with the new storeroom an elevator capable of simultaneously carrying two JMIC containers was added to service the storeroom from the main deck. After including these extra spaces the computer model was 're-balanced', meaning some of the ship's key parameters were adjusted back into accepted naval architecture specifications. A comparison was then made between the baseline DDG-51 design and the new intermodal container capable DDG-51 model to see how some of the key ship characteristics such as length, beam, displacement, and speed had been changed by the introduction of the new spaces to the ship. A brief summary of the results can be seen in Figure 47 and a detailed description of the analysis performed as well as a more complete listing of the results can be found in Appendix B.

Figure 47: Baseline FLT I DDG-51 vs. FLT I DDG-51 Including Central Storeroom

	Baseline DDG-51	Modified DDG-51	
Length	142	145	meters
Beam	18	18	meters
Displacement	8136	8169	tonnes
Speed	31.3	31.8	knots
Cost		+\$750,000*	dollars

*Cost increase estimate based on increased ship's displacement, using MIT Cost Model for ship design, does not include cost of redesigning ship systems displaced by central storeroom.

The results of the comparison show that consolidating storage spaces from throughout the ship into one central location does cause the ship to get larger. In the case of DDG-51 this meant increasing the length of the ship by three meters and adding approximately 33 metric tons of displacement. The reason the ship increases in size, even though the total square footage of storage space remains the same, is that the new central storage location displaces other systems that were previously located in its space. The displaced systems typically cannot be placed in areas where the dispersed storerooms were located; therefore, the ship has to get larger to contain all the necessary equipment within the hull envelope. The increased speed of the modified ship is somewhat counterintuitive, although because the original DDG-51 hullform has such a low length/beam ratio, lengthening the ship actually causes the resistance of the ship to decrease slightly and allows for a slightly faster maximum speed through the water.

It is important to note that simply combining disbursed storerooms into a central location and installing a JMIC capable elevator does not make a DDG-51 fully compatible with an intermodal container system. The purpose of this analysis was to determine the naval architecture effects of including a central storeroom and elevator in an existing warship design, not to redesign the warship to be fully JMIC compatible. In order to return the modified DDG-51 hullform to a working design the systems displaced by the central storeroom would have to be correctly reincorporated into the ship system, and further development of the internal ship intermodal container handling and transfer system would have to occur. It should also be noted that this analysis assumes the DDG-51 design is changed during the ship design phase. The changes made to a completed ship would have to be much different in scope, and would therefore have differing effects on the ship's architecture, not to mention the added expense of major ship alterations of an existing warship.

The economics behind including intermodal container system capabilities into future warship designs are complex. On the one hand it is generally agreed upon that intermodal container logistics will lower the overall cost of operating the naval logistics infrastructure (although by how much has yet to be determined). The contrasting argument is that including intermodal container capability into future warship designs will increase the size, complexity, and ultimately the cost of warship designs that in some cases have already been predicted to cost over \$2 billion per copy. At this juncture it is unclear which economic consideration will give the lowest overall cost for the United States Navy as it moves into the 21st century.

3. Breaking the Break-Bulk Mindset, a Complete Overhaul of Naval Logistics Practices.

In general today supplies are ordered for ships in less than unit-sized loads. Using food for an example, it would not be common for a small combatant underway to order a full pallet (or JMIC) of beans. A far more common order would be for two boxes of beans, two boxes of peas, ten containers of milk, etc., etc. Currently such a varied pallet of goods would be assembled within the holds of a T-AOE, by storekeepers breaking down pallets of unit loads, and then shrink wrapped for delivery to the final customer. Food was used as an example here, but the idea really applies to any class of naval supply.

One of the premises of efficiency gains associated with JMIC, or other intermodal containers, is that their contents will not be broken down and reassembled at intermediate supply stations. Obviously this idea conflicts with the current methods of naval ship resupply at sea. It is unclear how this issue could best be solved, but it is worth pointing out that besides bringing up compatibility issues, intermodal container systems are going to introduce procedural issues as well.

C. SUMMARY OF POTENTIAL COST SAVINGS ASSOCIATED WITH ADOPTING THE JMIC SYSTEM

At this point the development and implementation costs of the JMIC system are unknown. The program is just too early in its development cycle to estimate these costs with any degree of accuracy. Besides determining a proposed concept of operations for the JMIC system this thesis has attempted to investigate some of the possible savings associated with operating a small intermodal container system like JMIC within the naval logistics architecture.

Some of these potential savings are summarized on the following pages, with references back to sections in the body of the thesis if the reader would like more information.

1. Savings Associated with Loading JMICs Pierside (Section II.C.1)

It has been hypothesized that ordnance filled JMICs will be able to be loaded pierside at Naval Weapons Stations faster than the current practice of wooden pallets and specialized ordnance containers. The increase in loading speed with the JMIC system is based on possible increased stowage density of the JMIC containers and ease of handling the JMIC containers due to their standardized attachment points and lack of need for dunnaging. It currently takes 4-5 working days to load a T-AOE6 class ship with a full deployment load of ordnance at a Naval Weapons Station.

Potential Savings of JMIC System:

1. Each working day saved in T-AOE load time-\$85,000 (day rate for AOE-6)
2. Effective added pier capacity at Naval Weapons Station
3. Elimination of costly dunnaging
4. Increased magazine capacity at NWS by increasing stowage density and stacking ability

2. Savings Associated with Using JMICs in UNREP (Section II.C.3)

The JMIC system, when combined with Heavy UNREP capability, will greatly increase the connected replenishment throughput rates over the current STREAM system in use by the United States Navy. JMIC should increase the strike-up (taking material out of ship's holds for transfer to another ship) rates of the United States Navy's Combat Logistics Force fleet. Whether JMIC increases the strike-down rates of the receiving ships will be determined by the receiving ship's logistics transfer system design. When JMIC is used in conjunction with automated warehousing systems such as NAVSTORS, it has the potential for lowering the manpower requirements for the handling, storage, and transfer of ordnance.

Potential Savings of JMIC System:

1. CLF ships able to transfer material faster, conduct more daily UNREP evolutions, lower the number of CLF ships needed to support the fleet.
2. Decrease in manpower requirements of large deck ships weapons department by utilizing JMIC in conjunction with NAVSTORS system.
3. Decrease in manpower requirements of future large deck ships' supply departments, if the ships incorporate automated warehousing systems for general supplies.
4. Enabling automated accounting of supplies and ordnance, eliminating personnel required for paper-based accounting.
5. Possible increase in magazine stowage density, especially for smaller ordnance items.
6. Standard Interfaces decrease the number of handling slings necessary to conduct UNREP.

3. Savings Associated with Using JMIC in SeaBasing (Section II.C.5.b.1)

JMIC, or other small intermodal container systems are a SeaBasing enabler. In order to manage the high material throughput requirements of a SeaBase, supplies are going to have to be transported via ISO containers. While the standard sized commercial containers are necessary to integrate with the world's commercial shipping capabilities, their large size and weight makes them unwieldy to maneuver within the confines of a ship. By loading commercial ISO containers with smaller intermodal containers you can leverage the benefits of both systems, while minimizing their deficiencies. Small intermodal containers are more easily manipulated and transferred within the confines of a SeaBasing platform, and storing and transferring them within ISO containers allows them to be transported to the SeaBase using standard commercial ships, or specially adapted military ships with HiCASS capability.

Potential Savings of JMIC System:

1. Allows SeaBasing ship to utilize automated warehousing systems for internal transfer of small intermodal container cargo, enabling the high-cargo throughput necessary to make the SeaBasing system work.
2. Limits the size of the "breakout" area necessary aboard SeaBasing ships, thereby allowing the ships to be smaller, or use the space for other capabilities.
3. Enables the smart accounting technology necessary for making rapid SeaBased transfer of material possible.

4. Savings Associated with Using JMIC in the Battlefield (Section II.B.2.b)

The current method of delivering ordnance and supplies to the battlefield has many inherent deficiencies. Lack of asset visibility prevents the battlefield commander from knowing where his needed supplies are located, and often causes unnecessary reordering of ordnance and supplies. Restrictions on the safe stowage of ordnance components often mean that different components of the same ordnance system have to be stored in different containers. At the battlefield this often leads to the ordnance laydown area becoming a disorganized mess as the ordnance handlers' search from pallet to pallet looking for needed components. A JMIC system, incorporating RFID and blast hardening technology can address both of the aforementioned issues.

Potential Savings of JMIC System:

1. By enabling Total Asset Visibility (TAV) JMIC helps to eliminate the unnecessary reordering of supplies due to their unknown whereabouts and delivery times.
2. JMICs in concert with blast hardening technology allow all the components (i.e. warhead, fuses, propellant) to be packed together in the same container, helping to alleviate disorganization and lost components at forward ordnance laydown areas.
3. In future combat scenarios JMIC like systems could be used to deliver ordnance and supplies to forward operating units and be utilized as the unit's storage system.

The previous section is by no means a complete list of the potential cost savings, or uses, for a JMIC type intermodal container system. In Appendix C the thesis examines the net present value of three of the benefits mentioned; faster CLF loading, reduced large deck ship crew size, and faster CLF UNREPs. The present value of just these three benefits to the United States Navy is over \$1.5 billion dollars over a thirty-year time frame. Obviously some of the other benefits mentioned in this section of the thesis also have the potential to save the US Navy money in the operation of its logistics system, though for some of them it is currently very difficult to attach a realistic dollar value. As JMIC and other military and commercial intermodal container systems continue to develop, new uses and cost savings associated with each program will continue to be proposed and refined. Ultimately someone within the military leadership is going to have to weigh the potential uses and cost savings of intermodal container systems against the cost of implementing the systems themselves and see if the program is worth pursuing.

IV. CONCLUSIONS/ FUTURE WORK

To a layman incorporating a small standard sized container system into the military logistics architecture makes perfect sense. Standard sized containers allow for standard interfaces, which in turn allow standard handling equipment. It is easy to imagine how efficiencies could be improved throughout the logistics infrastructure if such a system were adopted.

However, the layman does not appreciate the complexities present in the often incompatible branches of military logistics. Focusing only on the Navy, there are many legacy incompatibility issues that will need to be corrected or consciously ignored if a JMIC like intermodal container system is to be introduced into the logistics pipeline. Not only that, but many future Naval ships, ships that will be operated for the next 30+ years, have been designed without intermodal container systems in mind. In some cases there is a possibility that the future ship designs could be altered to be more JMIC compatible, but in others the designs are so far advanced that it is unlikely for them to be changed.

In addition to compatibility issues there are long-standing procedural issues associated with break-bulk material handling that will have to be overcome in order to efficiently operate an intermodal container system within the naval logistics architecture.

JMIC and other intermodal container systems do offer a plethora of benefits and efficiencies to the military logistics pipeline if implemented properly. In all branches of the service there are legacy logistics system issues, and intra-branch compatibility issues that will need to be overcome if the adoption of a Joint Military Intermodal Container system is truly to be successful. As of the writing of this thesis it is unclear whether such a system will be able to overcome the obstacles in front of it and become part of the day-to-day military logistics architecture.

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APPENDIX A: STUDY OF UNREP MANNING ON LARGE DECK SHIPS

Questions Posed to Assistant Supply Officers of East Coast Large Deck Ships

1. How large is your Supply Department? How many of those personnel are directly involved in the UNREP evolution as it is taking place?
2. How many personnel from your Supply Department are normally sourced to work in the hangar bay and on the flight deck during a normal UNREP evolution?
3. How many personnel do you use to handle either paper-based or bar code type accounting during an UNREP evolution?
4. What is the normal size of the working party your ship calls to handle breakdown of pallets and storage of supplies below?

Question	CV-67	CVN-71	CVN-75	CV AVG
1	462	435	683	527
1a	150	200	125	158
2a	38	100	60	66
2b	37	20	23	27
3	10	10	4	8
4	150	150	350	217

Question	LHA-2	LHA-4	LHD-5	LHD-7	LHA avg
1	183	158	196	210	210
1a	29	158	150	179	179
2a	29	100	100	143	143
2b	0	0	10	20	20
3	4	7	8	7	7
4	100	175	100	225	225

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APPENDIX B: COMPARISON OF BASELINE DDG-51 WITH DDG-51 CONTAINING JMIC COMPATIBLE STOREROOM AND ELEVATOR

Problem: Modern warships are generally designed with small widely dispersed storerooms incapable of being effectively used for automated warehousing/intermodal container concepts.

Hypothesis: Dispersed storerooms could be combined into one central storeroom, a storeroom much better suited for use with intermodal container concepts. Creating a central storeroom will probably cause an increase in ship size, even though the aggregate amount of storage space remains constant. The increase in ship size will be due to the inability to place the systems displaced by the creation of the central storeroom back into the original spaces occupied by the dispersed storerooms.

Procedure: The Advanced Surface Ship Evaluation Tool (ASSET) developed by Naval Surface Warfare Center, Carderock Division (NSWCCD) was used to evaluate two separate computer models of a FLT I DDG-51 hull. The first computer model, hereafter termed **Baseline**, was simply the unaltered model of a DDG-51 included with the software package. The second computer model, hereafter termed **Modified**, was a modification of the **Baseline** hull. The **Modified** hull was modified to include a central storeroom and elevator capable of servicing intermodal container systems such as JMIC.

1. Original **Baseline** DDG-51 hullform contains 377 m² of space used for food and general storage.
2. **Modified** hullform incorporates 67% (253 m²) of this space in a two deck central storeroom (10 m X 17 m) located between frames 7 and 8, directly overhead of Auxiliary Machinery Room #2. The remaining 33% of available storeroom area is left dispersed throughout the **Modified** hullform. The remaining dispersed spaces are planned to be used for low-turnover items such as required spare parts.
3. **Modified** hullform also incorporates a cargo elevator capable of carrying two JMIC containers simultaneously. The elevators dimensions are 2.55 m X 1.6 m, and the trunk extends from the maindeck to the bottom deck of the central storeroom.

Results: Design summaries for **Baseline** and **Modified** can be found on the following page. The most notable effect of adding the central storeroom and elevator to the **Modified** hullform was the hullform increased by 3 meters in length and 33 tonnes in displacement. As predicted the larger hullform was necessary to contain the systems displaced by the creation of a central storeroom space.

**APPENDIX B (CONT.): COMPARISON OF BASELINE DDG-51 WITH DDG-51
CONTAINING JMIC COMPATIBLE STOREROOM AND ELEVATOR**

	DDG Baseline	DDG Modified	Units
Length Between Perpendiculars	142	145	m
Length Overall	150	153	m
Beam	18	18	m
Draft	6.3	6.3	m
GMT/B	0.089	0.083	
Max Speed	31.3	31.8	kts
Endurance (20 kts)	3808	3845	nm
Deck Area (Required)	6305	6555	m²
Deck Area (Available)	6115	6298	m²
Hull Volume (Required)	27974	28820	m³
Hull Volume (Available)	28228	28834	m³
Hull Structure Weight	3041	3097	mton
Full Load Displacement	8136	8169	mton
Dispersed Storeroom Area	377	124	m²
Central Storeroom Area	0	253	m²
# of elevators	1	2	
Cost		+\$750,000*	dollars

* Note: Increased cost is an estimate calculated by using the MIT Cost Model for ship design, and is due to the increased displacement of the modified ship. Cost estimate does not include costs incurred from redesigning the interaction of ship systems displaced by the centralized storeroom.

**APPENDIX C: NET PRESENT VALUE ANALYSIS OF SELECTED
JMIC SYSTEM BENEFITS OVER THE TIME FRAME 2010-2040**

Proposed Benefit: Decreased AOE/AE/T-AKE Loading Times

Assumptions: a. 10 Ammunition Ships in the fleet each year
b. Each ship conducts 4 major loadouts per year
c. Each loadout is conducted 1 day faster using JMIC system
d. Day rate for ships is \$85,000/day.
I. Uses OMB 30 year real discount rate for 2005 (3.1%)

# Ships	# Loadouts	Day Rate	Annual Savings
10	4	\$85,000	\$3,400,000

Year	Annual Savings	Discount Factor	Present Value
2010	\$3,400,000	0.86	\$2,918,674
2011	\$3,400,000	0.83	\$2,830,916
2012	\$3,400,000	0.81	\$2,745,796
2013	\$3,400,000	0.78	\$2,663,236
2014	\$3,400,000	0.76	\$2,583,158
2015	\$3,400,000	0.74	\$2,505,488
2016	\$3,400,000	0.71	\$2,430,153
2017	\$3,400,000	0.69	\$2,357,083
2018	\$3,400,000	0.67	\$2,286,211
2019	\$3,400,000	0.65	\$2,217,469
2020	\$3,400,000	0.63	\$2,150,795
2021	\$3,400,000	0.61	\$2,086,125
2022	\$3,400,000	0.60	\$2,023,399
2023	\$3,400,000	0.58	\$1,962,560
2024	\$3,400,000	0.56	\$1,903,550
2025	\$3,400,000	0.54	\$1,846,314
2026	\$3,400,000	0.53	\$1,790,799
2027	\$3,400,000	0.51	\$1,736,954
2028	\$3,400,000	0.50	\$1,684,727
2029	\$3,400,000	0.48	\$1,634,071
2030	\$3,400,000	0.47	\$1,584,938
2031	\$3,400,000	0.45	\$1,537,282
2032	\$3,400,000	0.44	\$1,491,059
2033	\$3,400,000	0.43	\$1,446,226
2034	\$3,400,000	0.41	\$1,402,741
2035	\$3,400,000	0.40	\$1,360,564
2036	\$3,400,000	0.39	\$1,319,655
2037	\$3,400,000	0.38	\$1,279,975
2038	\$3,400,000	0.37	\$1,241,489
2039	\$3,400,000	0.35	\$1,204,160
2040	\$3,400,000	0.34	\$1,167,954

Net Present Value of Benefit

\$59,393,522

APPENDIX C (CONT.): NET PRESENT VALUE ANALYSIS OF SELECTED JMIC SYSTEM BENEFITS OVER THE TIME FRAME 2010-2040

Proposed Benefit: Reduced Supply and Weapons Department Manning on Future Large Deck Ships

- Assumptions:
- a. Supply/Weapons Department Manning are expected to decrease 20% due to manning initiatives
 - b. JMIC, combined with smart warehousing technology will contribute to 5% of the 20% reduction
 - c. Aircraft Carrier Supply Department assumed to be 527 people (Appendix A)
 - d. Aircraft Carrier Weapons Department assumed to be 450 people
 - e. Amphibious Ship Supply Department assumed to be 187 people (Appendix A)
 - f. Amphibious Ship Weapons Department assumed to be 100 people
 - g. Annual average cost of a sailor assumed to be \$90,000/year
 - h. Assumes a fleet size of 10 Aircraft Carriers and 10 Large Deck Amphibs
 - i. Uses OMB 30 year real discount rate for 2005 (3.1%)

CVN	Manning Reduction	# Ships	\$/sailor	Total Annual Savings
Supply	26.35	10	\$90,000	\$23,715,000
Weapons	22.5	10	\$90,000	\$20,250,000
LHA/R	Manning Reduction	# Ships	\$/sailor	Total Annual Savings
Supply	9.35	10	\$90,000	\$8,415,000
Weapons	5	10	\$90,000	\$4,500,000

**APPENDIX C (CONT.): NET PRESENT VALUE ANALYSIS OF
SELECTED JMIC SYSTEM BENEFITS OVER THE TIME FRAME 2010-2040**

*Proposed Benefit: Reduced Supply and Weapons Department Manning on
Future Large Deck Ships (cont.)*

Year	Annual Savings CVN	Annual Savings LHA/R	Discount Factor	Present Value
2010	\$43,965,000	\$12,915,000	0.86	\$48,827,699
2011	\$43,965,000	\$12,915,000	0.83	\$47,359,553
2012	\$43,965,000	\$12,915,000	0.81	\$45,935,551
2013	\$43,965,000	\$12,915,000	0.78	\$44,554,366
2014	\$43,965,000	\$12,915,000	0.76	\$43,214,710
2015	\$43,965,000	\$12,915,000	0.74	\$41,915,334
2016	\$43,965,000	\$12,915,000	0.71	\$40,655,028
2017	\$43,965,000	\$12,915,000	0.69	\$39,432,617
2018	\$43,965,000	\$12,915,000	0.67	\$38,246,962
2019	\$43,965,000	\$12,915,000	0.65	\$37,096,956
2020	\$43,965,000	\$12,915,000	0.63	\$35,981,529
2021	\$43,965,000	\$12,915,000	0.61	\$34,899,640
2022	\$43,965,000	\$12,915,000	0.60	\$33,850,281
2023	\$43,965,000	\$12,915,000	0.58	\$32,832,474
2024	\$43,965,000	\$12,915,000	0.56	\$31,845,271
2025	\$43,965,000	\$12,915,000	0.54	\$30,887,751
2026	\$43,965,000	\$12,915,000	0.53	\$29,959,021
2027	\$43,965,000	\$12,915,000	0.51	\$29,058,216
2028	\$43,965,000	\$12,915,000	0.50	\$28,184,497
2029	\$43,965,000	\$12,915,000	0.48	\$27,337,048
2030	\$43,965,000	\$12,915,000	0.47	\$26,515,081
2031	\$43,965,000	\$12,915,000	0.45	\$25,717,828
2032	\$43,965,000	\$12,915,000	0.44	\$24,944,547
2033	\$43,965,000	\$12,915,000	0.43	\$24,194,517
2034	\$43,965,000	\$12,915,000	0.41	\$23,467,039
2035	\$43,965,000	\$12,915,000	0.40	\$22,761,434
2036	\$43,965,000	\$12,915,000	0.39	\$22,077,046
2037	\$43,965,000	\$12,915,000	0.38	\$21,413,236
2038	\$43,965,000	\$12,915,000	0.37	\$20,769,385
2039	\$43,965,000	\$12,915,000	0.35	\$20,144,893
2040	\$43,965,000	\$12,915,000	0.34	\$19,539,179

Net Present Value of Benefit

\$993,618,689

APPENDIX C (CONT.): NET PRESENT VALUE ANALYSIS OF SELECTED JMIC SYSTEM BENEFITS OVER THE TIME FRAME 2010-2040

Proposed Benefit: CLF ships conduct more efficient UNREPs with JMIC System

- Assumptions:
- a. CLF ships are able to conduct 10% faster material transfer using JMIC system and Heavy UNREP
 - b. 10% faster transfer results in a 5% reduction in CLF fleet size
 - c. CLF fleet consists of 30 ships that conduct UNREPs
 - d. The average day rate for the CLF fleet is assumed to be \$50,000
 - e. Uses OMB 30 year real discount rate for 2005 (3.1%)

CLF Ships	Ship Reduction	Annual Savings
30	1.5	\$27,375,000

Year	Annual Savings	Discount Factor	Present Value
2010	\$27,375,000	0.86	\$23,499,618
2011	\$27,375,000	0.83	\$22,793,034
2012	\$27,375,000	0.81	\$22,107,695
2013	\$27,375,000	0.78	\$21,442,963
2014	\$27,375,000	0.76	\$20,798,219
2015	\$27,375,000	0.74	\$20,172,860
2016	\$27,375,000	0.71	\$19,566,305
2017	\$27,375,000	0.69	\$18,977,987
2018	\$27,375,000	0.67	\$18,407,359
2019	\$27,375,000	0.65	\$17,853,888
2020	\$27,375,000	0.63	\$17,317,059
2021	\$27,375,000	0.61	\$16,796,372
2022	\$27,375,000	0.60	\$16,291,340
2023	\$27,375,000	0.58	\$15,801,494
2024	\$27,375,000	0.56	\$15,326,376
2025	\$27,375,000	0.54	\$14,865,545
2026	\$27,375,000	0.53	\$14,418,569
2027	\$27,375,000	0.51	\$13,985,033
2028	\$27,375,000	0.50	\$13,564,532
2029	\$27,375,000	0.48	\$13,156,675
2030	\$27,375,000	0.47	\$12,761,082
2031	\$27,375,000	0.45	\$12,377,383
2032	\$27,375,000	0.44	\$12,005,221
2033	\$27,375,000	0.43	\$11,644,249
2034	\$27,375,000	0.41	\$11,294,131
2035	\$27,375,000	0.40	\$10,954,541
2036	\$27,375,000	0.39	\$10,625,161
2037	\$27,375,000	0.38	\$10,305,684
2038	\$27,375,000	0.37	\$9,995,814
2039	\$27,375,000	0.35	\$9,695,261
2040	\$27,375,000	0.34	\$9,403,745

Net Present Value of Benefit	\$478,205,197
Total Net Present Value of 3 Benefits Analyzed	\$1,531,217,409

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